PROJECTS THEORY APPLICATIONS CIRCUITS TECHNOLOGY

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July 2010

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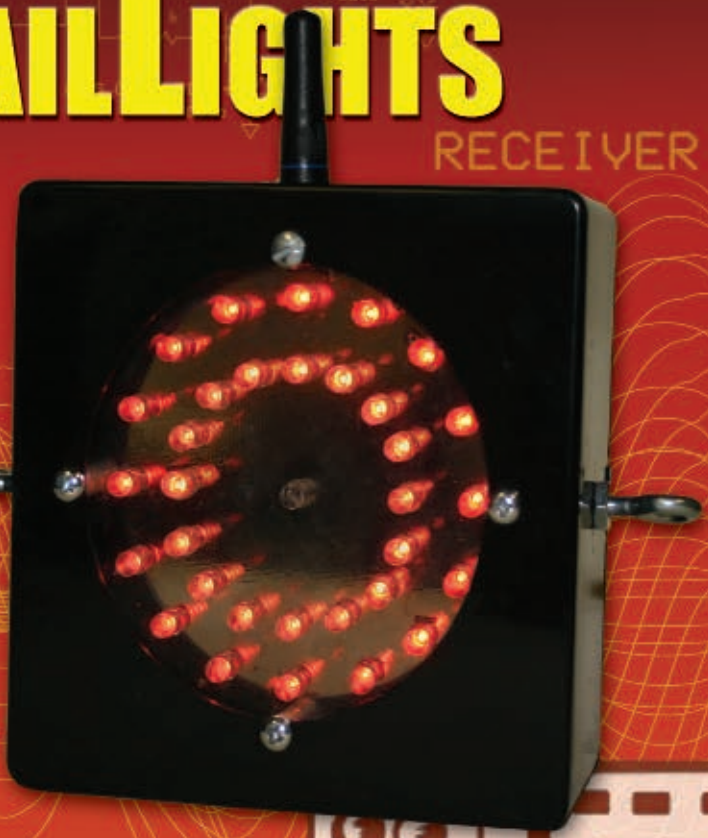

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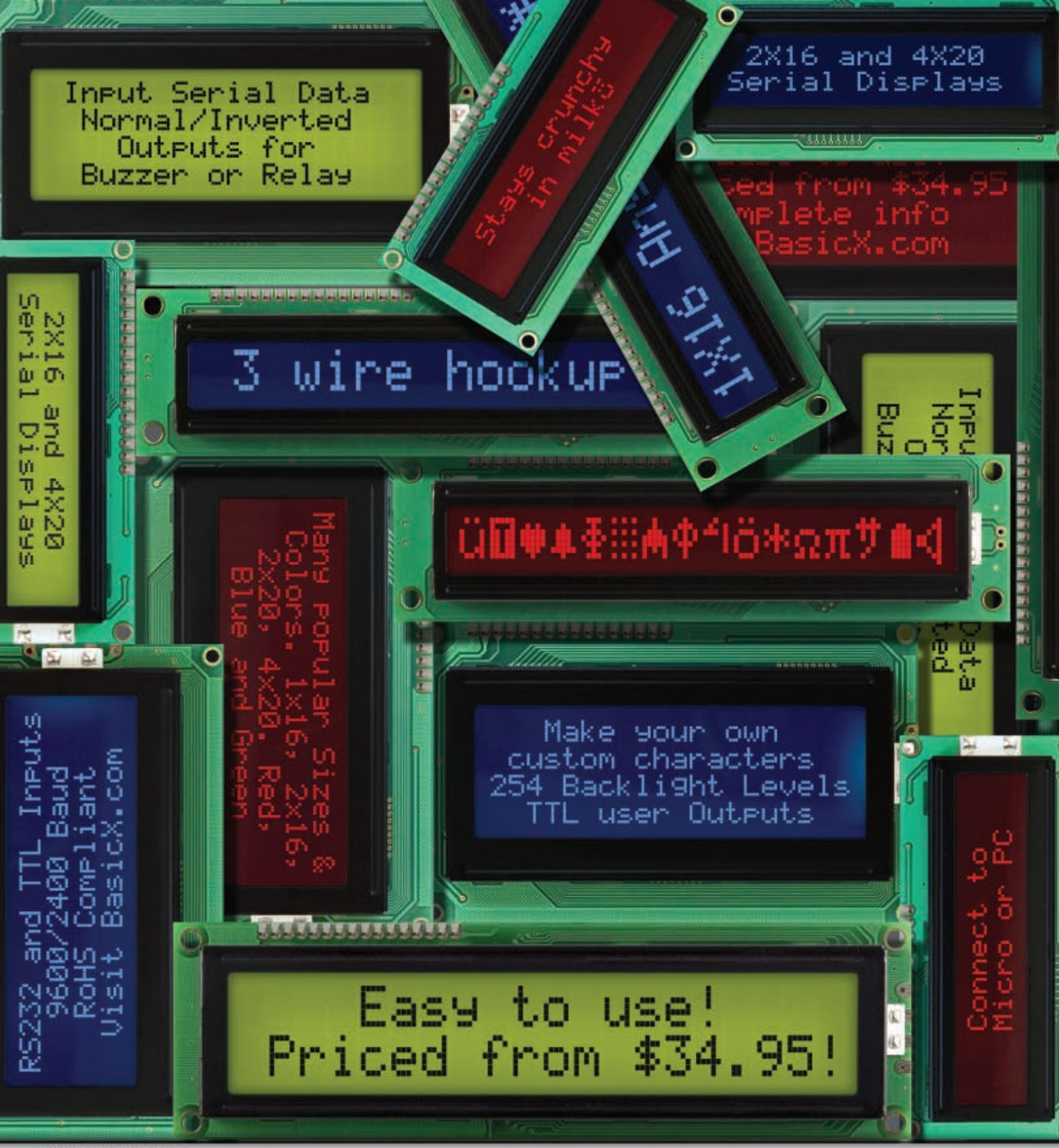

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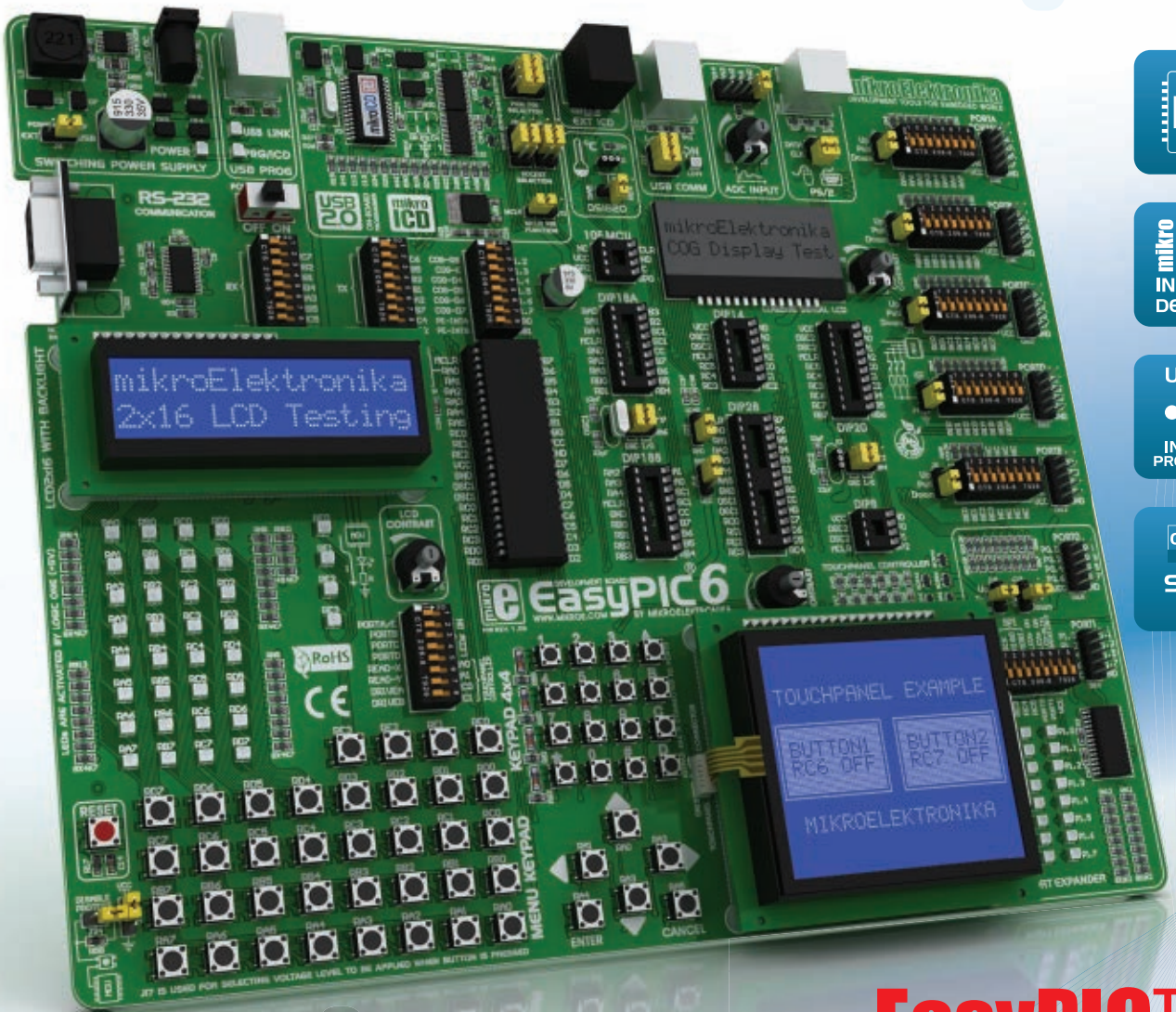

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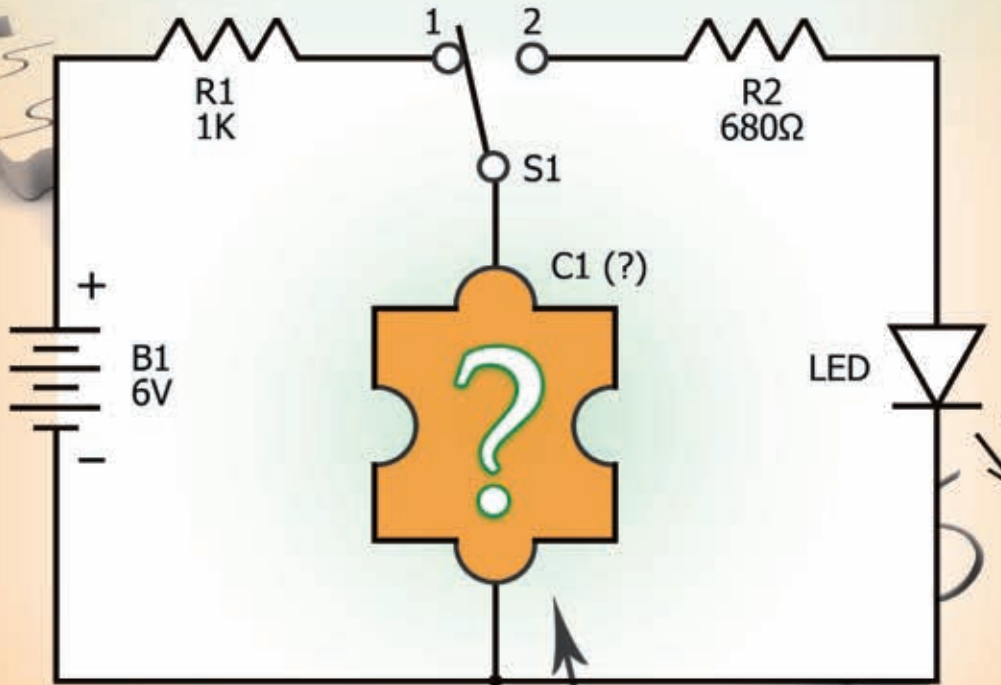

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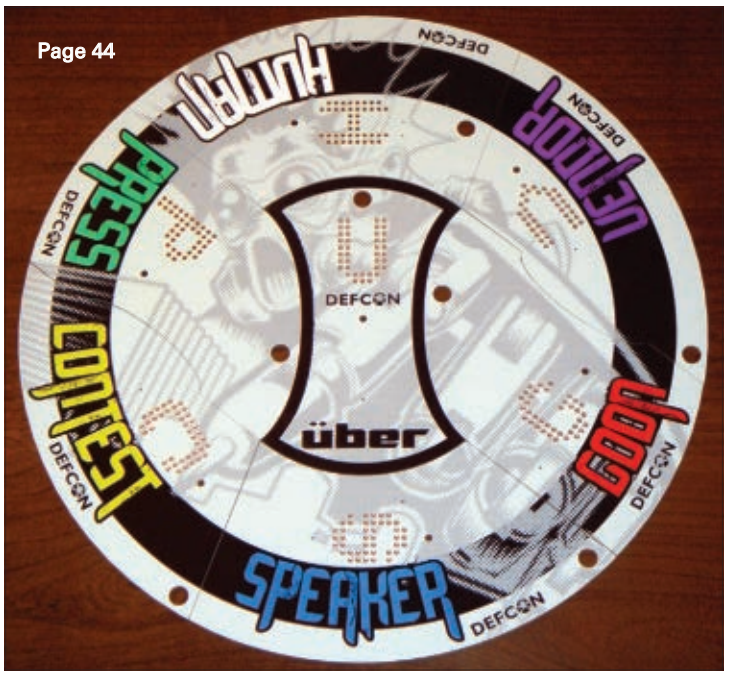


Columns

10 TechKnowledgey 2010
Events, Advances, and News
Solar airplane takes flight, what's old is new again (think Commodore 64), compact AC/DC power supplies, plus other stuff you'll find interesting.

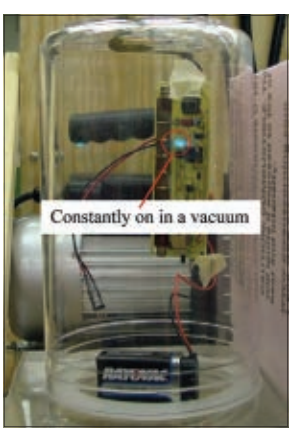
14 The Spin Zone
Adventures in Propeller Programming
Propeller Time

22 Q & A
Reader Questions Answered Here
Power supply, mystery component, convert DC meter to AC, plus more.

52 Smiley's Workshop
Programming • Hardware • Projects
AVR Memory Part 2: EEPROM

58 The Design Cycle
Advanced Techniques for Design Engineers
Bringing a USB-to-UART Protocol Converter to Life

67 Near Space
Approaching the Final Frontier
They Came From Outer Space! (Cosmic Rays, That Is!)



Projects & Features

29 Build the Self-Locking Box
Design your own RFID-controlled box that only you can open.
■ *By Corbin Adkins*

34 Wireless Trailer Taillights
Keep your trailer in tow with this handy device.
■ *By Ron Newton*

38 Experiments with Alternative Energy
Learn the fundamentals of renewable energy through this educational series.
This month: Build the Telematics Car.
■ *By John Gavlik*

44 Making the DEFCON 17 Badge
Joe's annual commentary of what it took to pull off another innovative design for the badge of a very unique event.
■ *By Joe Grand*

Departments

08	DEVELOPING PERSPECTIVES	72	NV WEBSTORE
27	NEW PRODUCTS	76	CLASSIFIEDS
28	SHOWCASE	78	TECH FORUM
66	ELECTRO-NET	81	AD INDEX

FUNdamentals For Beginners

Just getting started in electronics? Try these simple demos to illustrate electronics principles and how components function in actual circuits!

64 What a Diode Does

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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

Wearable Computing

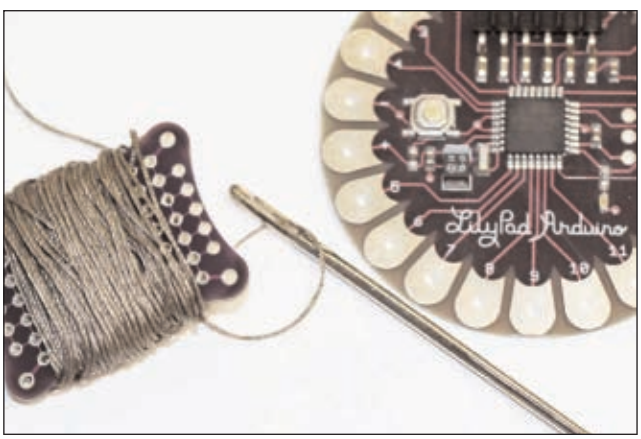
Several years ago, I consulted on a project on body area networks for the DoD. The idea was to create a system of wearable sensors that would enable someone in a distant command center to monitor the health of every soldier in the field. The initial idea centered around a watch and a satellite antenna embedded in a standard military helmet. The project never gained traction, in part because of the expense of the system, and in part because of the weight/bulk burden placed on wearers.

Fast-forward to the present, and it's imminently possible for every hobbyist to afford a body area network of their own. Miniature sensors are now affordable, easy to work with, and reasonably accurate. Moreover, low power, wearable processing power can be obtained off-the-shelf. For example, take the Arduino LilyPad, which I bought from SparkFun Electronics (**www.sparkfun.com**).

As shown in the accompanying photo, the two-inch diameter disc carries a microprocessor, reset button, LED, and assorted support components. More importantly, all of the significant I/O ports and power are brought to the periphery of the board, where the board can be connected — via conductive thread — to sensors and actuators. Instead of soldering, you tie a knot with the silver-impregnated thread and connect the other end to a sensor or other device. The beauty of using thread and a sewing needle instead of wire and solder is that the disc can be embedded without fear of the connections breaking due to stress on copper wires. I was first drawn to the LilyPad because it could withstand the elements. The LilyPad can be washed, as can the conductive thread. I haven't washed either, but I have no doubt both would withstand at least a quick rinse in the shower. There is some talk on the Web suggesting some of the silver in the thread can be washed out, so don't get overly vigorous.

If you've worked with any incarnation of the Arduino, then you know the LilyPad. However, the conductive thread is another matter. It lends itself to all sorts of projects, while presenting new circuit design challenges. For example, once you start working with the non-insulated conductive thread, you'll appreciate the PVC jacket on ordinary wire. With conductive thread, even a simple circuit becomes a traveling salesman problem. There are simple tricks of keeping separate threads electrically isolated, such as placing stitching on opposite sides of the cloth substrate. When all else fails, I resort to pushing a needle and thread through the PVC insulation. There's a penalty in terms of flexibility over the raw conductive thread, but it's minor.

I've used the thread to create pressure sensors (run two pieces of conductive thread in parallel through carbon-impregnated foam), to provide super-flexible wiring to sensors embedded in a haptic glove, and to create surface sensors in a shirt designed to pick up cardiac electrical activity for an electrocardiogram (EKG) monitor. I'm sure you can think of additional uses for a



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conductive thread capable of carrying microcontroller I/O and modest power. If, by chance, you're new to the Arduino line of open source hardware and software, the LilyPad is a relatively painless place to start. You can get complete kits with thread and an assortment of sensors and actuators from SparkFun, and there's plenty of Arduino info on the Web. The greatest limitation of the LilyPad — compared with the other Arduino formats — is the relative lack of shields or function-specific plug-in extender boards. Fortunately, there is an XBee RF Module shield which enables you to free your projects from the Mac/PC USB tether and still communicate with your desktop or other Arduinos connected to an XBee transceiver. If you've created a wearable computing device that does more than blink embedded LEDs, please send in a photo and a short description. It could serve as an inspiration for the rest of us to get out our sewing kits and start stitching. **NV**

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TECH KNOWLEDGEY 2010

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

NANO INVASION CONTINUES

There doesn't seem to be any limit to the number of researchers who want to inject nanoscale things into our bloodstreams, and the trend continues at Purdue University (**www.purdue.edu**). The idea of sending in little rod-like or spherical things and illuminating them isn't new, but an improved approach — developed by Prof. Ji-Xin Cheng and associates — shines near-infrared laser pulses through your skin to excite tiny gold-silver alloy "nanocages" and other particles, and generate images. The particles — about 40 nm wide — are stimulated by a phenomenon called "three-photon luminescence" which employs 80 million laser pulses per second to illuminate various tissues or organs. Unlike previous approaches, the technique does not require "plasmons" (clouds of electrons moving in unison) for image enhancement, so the associated generation of tissue-damaging heat is avoided. In addition, it creates "third harmonic generation" which also enhances brightness. The result is images that are ten times brighter than those produced by other experimental imaging approaches. It is also suggested that the nanocages might eventually be used to deliver time-released anticancer drugs. ▲

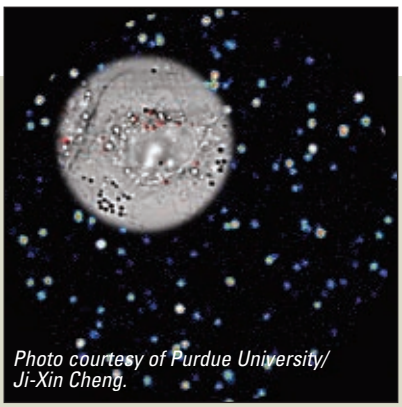
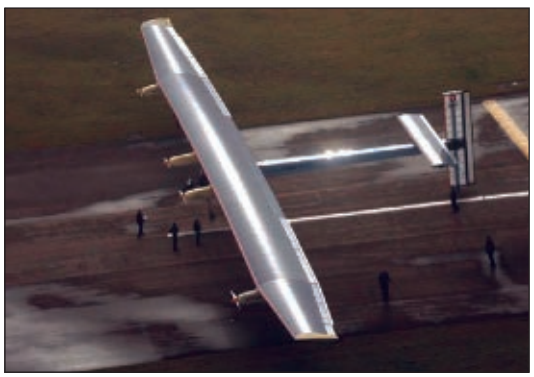


Photo courtesy of Purdue University/ Ji-Xin Cheng.

■ Laser-excited luminous nanocages surround a living cell.



■ The Solar Impulse slips down the runway in a performance test.

SOLAR AIRPLANE TAKES FLIGHT

Unmanned solar air vehicles have been around for years, but on April 7 while a crowd of spectators watched the human-piloted Solar Impulse HB-SIA took off from Switzerland's Payerne airfield, climbed to nearly 4,000 ft (1,200 m), and went through various flight exercises for the next 87 minutes. We'd love to provide details, but the project website (**www.solarimpulse.com**) is long on speculation (environmental niceties, a planned nonstop flight around the world, and so on) and strangely short on specs. However, various sources have tagged the plane as about 72 ft (22 m) long with a wingspan of 208 ft (63.4 m), and powered by nearly 12,000 photovoltaic cells and a pack of lithium batteries. The four 10 hp electric motors will move the 3,500 lb (1,600 kg) bird along at a bit over 40 mph (70 kph). And that's about all we know. ▲

MOTION DETECTION SIMPLIFIED

It's relatively easy to find a complicated solution to a complicated problem, but it takes real creativity to find a simple solution. Accordingly, researchers at MIT's Center for Bits and Atoms (**cba.mit.edu**) have created a stir with a new concept for motion detection based on what is basically just a small metal bead suspended in a hole in a circuit board. A fluctuating electric field holds the bead in a tight orbit within the hole, and by detecting disturbances in the bead's orbit, one can sense the sensor's direction of motion. Apparently, the "microdynamical" device can replace at least six different micromechanical ones. It measures linear motion in 3D which normally would require three accelerometers. It can also recognize its orientation (whether it's tipped or rotated) for which you would usually need three gyroscopes. The potential significance of the device is illuminated by the fact that the three-axis accelerometer is the most expensive part of a Wii remote, and the new device could

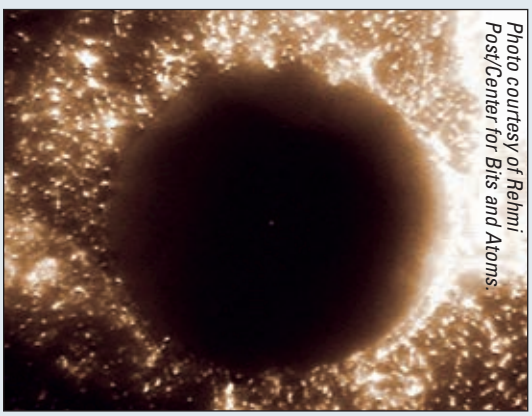


Photo courtesy of Rehmi Post/Center for Bits and Atoms.

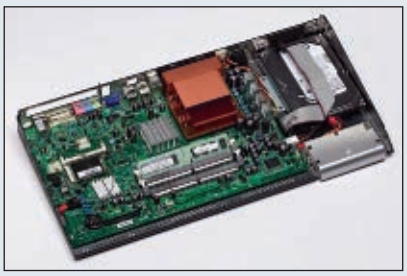
■ The barely detectable bead in the center of the black hole is used to generate six-degree motion detection.

COMPUTERS AND NETWORKING

WHAT'S OLD IS NEW AGAIN

Back in the '80s, a local computer shop was raffling off some computer equipment for charity. The joke was that first prize was a Commodore 64 computer, and second prize was two Commodores. But despite the plastic exterior and limited capabilities, it was cheap for its day ($595, eventually dropping to $199), and company founder Jack Tramiel says they sold somewhere between 22 and 30 million of them. (Sounds like accounting might have been one of the company's problems.) Well, if you are among the dozen or so individuals who still cherish the classic, or perhaps someone who clings desperately to his beloved Amiga, you might be glad to know that by the time you read this, the new Commodore Phoenix should be on the market — unless Barry Altman, founder of the new Commodore USA, has failed to secure the right to use the Commodore name, in which case it will probably be called something else. Or, it might be called the Commodore 64 again which would be appropriate given its 64-bit processor. At last report, Barry wasn't sure yet. Well, don't sweat the details, I always say.

■ Commodore 64's great grandson: the Phoenix.



In any event, the new model resembles its namesake in that you get the keyboard and CPU in one unit, but that's about the only similarity. The new one is driven by an Intel Core2 Duo or Core2 Quad processor, and includes an Intel Graphics Media Accelerator 3100. It supports up to 4 GB of memory and comes with Gigabit Ethernet, a DVD-RW drive, and a 500 GB hard drive. No price information was available at press time, but if you visit **www.commodoreusa.net**, you can get more details and even download the 46 page owner's manual. ▲

NEED SPEECH SOFTWARE?

Those of us who wasted a fair amount of time with IBM's ViaVoice program some years ago tend to be skeptical of transcription software, but Nuance (**www.nuance.com**) offers a family of products that claim "up to" 99 percent accuracy. Of course, I can walk "up to" 99 miles, but don't hold your breath. On the Mac side of things, you have the $149 MacSpeech Scribe which has just been updated to fix some user-reported issues. The free fix includes the MacSpeech Scribe Medical and MacSpeech Scribe Legal versions, and users can make the update from directly within the application. If you have a Power Mac or are running any OS older than Snow Leopard, you're out of luck, however.

On the PC side, you have Dragon NaturallySpeaking 10 which runs from $99 for the Standard version, up to $1,199 for the high-end Legal package. The full lineup of products can be viewed at the website. If you live in the UK, use **www.macspeech.co.uk**; Canadians can visit **www.macspeech.ca**; and Aussies are directed to **www.macspeech.com.au**. Oh, and if you ever wondered what happened to Omnipage OCR software, that's a Nuance product now, too. ▲

MOTION DETECTION SIMPLIFIED *CONTINUED*

potentially replace it at a tenth of the cost. Other cited possible applications include navigation where GPS information is too imprecise, viewing a 3D virtual object on your cell phone simply by moving it around, and using a pen that can digitally record everything that's written with it. Don't expect to see these things on the market soon, though, as a couple problems remain.

First, it takes about 1,000V in the prototype to suspend the bead which is asking a lot of a hand-held, battery-powered device. Plus, you need a better way of measuring its oscillation. The prototype uses a miniature camera, and a more practical kind of optical sensor — or some other detection method — would have to be developed for incorporation in the device. But as Analog Devices Michael Judy noted, "If they can get all six degrees out of it, it would be huge. That's the holy grail right now in the human interface to electronics." ▲

WEBSITE AIDS IN REPAIRS

If you are in the habit of breaking things and want to fix them yourself, you might want to check out **www.ifixit.com** which bills itself as a "repair manual that you can edit." Even though the home page features a bicycle job, it appears that the site is geared mostly to electronics. The Repair Manuals page includes instructions for Macs, iPods, and iPhones, as well as for vehicles, game consoles, cameras, and others. There is also a troubleshooting section that, as of now, includes more than 5,000 questions and answers. Plus, it's a bit of a wiki concept in that you are encouraged to contribute to the knowledge base. Finally, you can sign up for a repair newsletter that reportedly already has 40,000 recipients on the list. Best of all, it's free. ▲

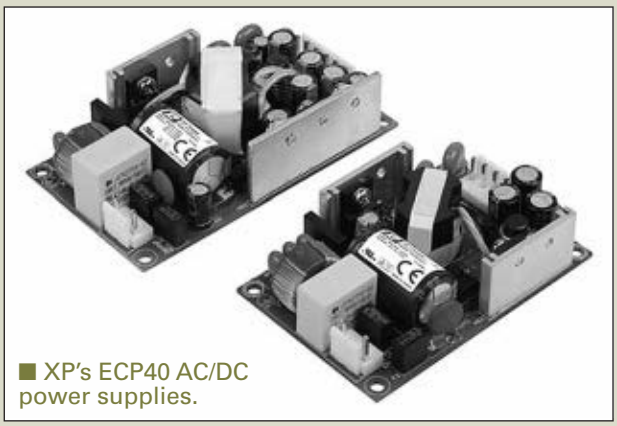
CIRCUITS AND DEVICES

AVOID THOSE PESKY CAMERAS

■ Beat the system with the Escort SC55 camera locator.

Law enforcement agencies across the country are increasingly fitting street intersections with "safety cameras" which a cynic might say is a euphemism for "revenue enhancement cameras." But for every gadget there eventually will be an anti-gadget, and Escort (**www.escortradar.com**) has stepped up to the plate with the SC55 Safety Camera Locator. The device adds GPS intelligence and Escort's Defender™ Database to provide drivers with early warning notification of approaching speed traps, speed cameras, red light cameras, and other high-target traffic citation threat areas. The SC55 is designed to work with older Escort/Beltronics non-GPS enabled radar detectors, or it can be used as a stand-alone unit. Reportedly, the Defender Database scored 95 out of 100 for overall accuracy in a **RadarTest.com** independent test, beating the nearest competitor by 29 points. The secret seems to be the database doesn't merely add new camera locations over time — existing data points are verified for continued relevance and removed if no longer in force. Database updates can be downloaded from the website via your computer and a USB connector. The basic unit retails for $159.95, or $179.95 if you want the optional Detector Kit. ▲

COMPACT AC/DC POWER SUPPLY



■ XP's ECP40 AC/DC power supplies.

One of the latest from XP Power (**www.xppower.com**) is the ECP40 series of 40W AC/DC compact power supplies. Single-output models provide outputs from +5 to +48 VDC, and the dual-output units offer combinations of +5 VDC and +12, +15, or 24 VDC outputs. Triple output units add +12, -12, or -15 VDC options. All accommodate inputs of 85 to 264 VAC. The units also feature a peak load capability that allows them to deliver 130% of rated power for up to 30 sec, so you can use them to, e.g., start motors without having to specify a higher rated supply. They can operate in environments from -10 to +70°C without additional heatsinking or a forced air flow. The units meet both IEC60601-1 (medical) and IEC60950 (IT and industrial) specs, and comply with EN55022 level B standard for both conducted and radiated emissions. Overvoltage, overload, and short-circuit protection features are included. ▲

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One thing you can say about the IEEE Electromagnetic Compatibility Society's annual symposium: It's usually planned with an eye on entertainment. Last year, between two and three thousand EMC folks streamed into Austin, TX, where you can stroll down Sixth Street and hear all kinds of live music, drink cheap beer, and stuff yourself at one of the renowned restaurants. All you have to do is dodge the biggest army of panhandlers south of Seattle. (I recommend the Jackalope on two-for-one burger night.) This year, the interference gurus are converging July 25 through 30 at the Greater Ft. Lauderdale/Broward County Convention Center to experience "waves of relaxation as you discover a fresh and casual blue wavy beach world filled with megayachts, alfresco dining, outlet shopping, eco-adventure, arts, and beyond; from Hollywood in the south to Pompano and Deerfield Beach in the north, to the exotic Everglades." The Rustic Inn Crabhouse comes highly recommended, so pack up your spectrum analyzer and head for the airport. There's even financial support available for "selected economically disadvantaged engineers" which could include nearly anyone who has paid their $175 annual IEEE membership dues.

Oh, yeah. There will be a bunch of exhibits, tutorials, and things like that. Details at **www.emc2010.org**. **NV**

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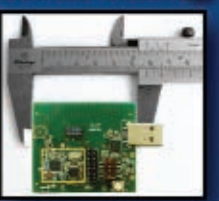

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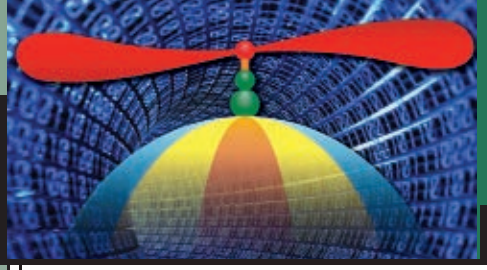

■ BY JON WILLIAMS

PROPELLER TIME

A couple months ago, I created an encoder object for my friend, Wayne ("the Brain"). It turns out that Wayne's project is a multi-function timer which I helped him improve a bit through the use of a very simple – no assembly required – timer object. The Propeller's architecture gives us the ability to be fairly precise about timing without much effort, and I thought it was time we delve into that a bit. Timing, that is.

SLOW DOWN!

It is somewhat humorous that we all demand faster processors and then turn around and do things to slow them down, usually to create delays for blinking LEDs and similar processes. Of course, using the Propeller, we could easily launch a blinking LED cog, but this use of resources is not always required.

Since the BASIC Stamp 1 (released in 1993), most of us have become accustomed to **PAUSE**. Very handy — so much so that you can find some variant of it in nearly every embedded language going. Except Spin, that is ... so, what gives?

Keep in mind that the Spin interpreter runs in a cog and, therefore, must be very trim. What this means for us — especially those who migrated from some form of embedded Basic — is that a lot of niceties we've used in the past just don't exist in Spin (we discussed this last time when creating a method to emulate PBASIC's **SHIFTIN** function).

The Propeller does have a method for creating delays but it takes a bit of getting used to and must be used carefully. Once you get used to it, however, you'll find it very handy. That method is called **WAITCNT**. This command — as its name suggests — will wait for the system counter (**CNT**) to reach a *specific* value. Until it does, the cog executing **WAITCNT** is put into low power mode.

The trick with **WAITCNT** is that it is waiting for a *specific* value in the system counter, not waiting a given duration as with **PAUSE**. When using **WAITCNT**, then, we typically need to involve the current system counter value in the target parameter. For example, if we wanted to create a delay of 1/4 second, we can do it like this:

```
waitcnt(cnt + (clkfreq >> 2))
```

As you can see, we're taking the system frequency (clock ticks per second) and shifting it right by two (which is a more efficent way to divide by four) to get the number of clock ticks in 1/4 second, then adding this to the system counter. This gives us a 250 ms delay but I think you'll agree that this line of code is not terribly obvious to the casual programmer.

Another possible problem can arise if the target for **WAITCNT** has just passed. Since Spin is an interpreted language, it takes a bit of time to execute instructions, and if the specified target has passed we can end up with a delay of nearly 54 seconds at 80 MHz (because we have to wrap all the way around to the intended value). Zoinks.

With just a little programming, we can have the convenience of **PAUSE**, making our programs — those that can tolerate inline delays — easier to read and maintain. Let's give that a go.

To create a method to emulate **PAUSE**, we'll need to know how many clock ticks are in one millisecond; this will be used with **WAITCNT**. While we could divide **CLKFREQ** by 1000 in the working part of the program, I think a better way is to create a constant. At the top of my default Spin template, I have the following code:

```
CON

  _clkmode = xtal1 + pll16x
  _xinfreq = 5_000_000
' _xinfreq = 6_250_000

  CLK_FREQ = ((_clkmode-xtal1)>>6)*_xinfreq
  MS_001   = CLK_FREQ / 1_000
```

The first few lines are standard fare, setting the clock mode and input frequency — we see this in almost every Spin program. You'll note I've got my template set up to easily move between 80 and 100 MHz projects. The next section — some clever code from a Propeller forum member whose name escapes me (*sorry!*) — calculates the number of clock ticks per millisecond based on the initial

settings. Since constants are pre-calculated by the compiler, this adds no overhead to program at run time.

Now, we can create a method to emulate **PAUSE**:

```
PUB pause(ms) | t

  t := cnt
  repeat ms
    waitcnt(t += MS_001)
```

On entry, we immediately capture the value of the system counter — this is the starting point for the delay. Next, we drop into a **REPEAT** loop for the desired number of milliseconds. In the **WAITCNT** instruction, we add the number of ticks per millisecond to the starting value. What this does for us is account for the time used to run the loop and set up the **WAITCNT** instruction each time through. Remember, **WAITCNT** is looking for a specific target and the system counter is always running as we're working our way through the code.

If we re-read the system counter in the **WAITCNT** instruction, several microseconds would be added to each loop — for long delays, this could become a problem. By reading **CNT** before the loop, we ensure that each time through runs exactly 1 ms. The Propeller manual has a great description of this process called synchronized delays; we'll put this strategy to use often.

HOW LONG?

About 10 years ago, I created an alarm product that used the BASIC Stamp 2 microcontroller. The product didn't need much in the way of resolution (100 ms per "tick"), but a tick needed to be 100 ms no matter what path the program took. To make this happen, I had to measure the various paths in the code and pad them to get to a consistent 100 milliseconds per path.

This process was tedious, to say the least. I used a spare output pin, setting it high (at the start of a code section) and low (at the end of a code section), and monitoring it with an oscilloscope to measure code execution time. Boy, was I glad to get that project finished. It took as long to tune the program timing as it did to write the baseline code!

With multiple cogs and the **WAITCNT** instruction, it's not likely we'd ever go through this process when using the Propeller, but we might want to measure a bit of code to check for performance. This is really helpful when experimenting with variations on code. With the Propeller, we don't need a spare pin or an oscilloscope. We can do this with a couple variables and a terminal program (connected to the programming port). The ability to time a code segment requires just a few lines to be added to our template:

```
PUB main | t0, t1

  term.start(31, 30, %0000, 115_200)
  pause(1)
  term.tx(CLS)
  repeat
    t0 := cnt

    ' code to test goes here

    t1 := cnt
    t1 := ||(t1 - t0)

    term.tx(HOME)
    term.dec(t1)
    term.tx(CLREOL)
    pause(1_000)
```

After starting a serial object so that we can send the timing result to a terminal, the program drops into a **REPEAT** loop where we set *t0* to the present system counter. After this, we'll insert a bit of code to test (not yet, though). After the code, we grab the system counter again and put it into variable *t1*. Now we can take the difference between the two. Since **CNT** is a free-running 32-bit counter, we need to use the absolute (||) operator on the difference between *t1* and *t0*. Note, too, that this process should only be used on short-term events.

When I run the program on my Propeller platform, I get 368 counts with no code inserted between the *t0* and *t1* checkpoints. Knowing this, we can update the calculation as follows:

```
    t1 := (||(t1 - t0) - 368) #> 0
```

The subtraction of 368 is obvious; the rest of the line ensures that we do not dip below zero. Another point: Since we're working with system clock ticks, the value does not change with frequency,

For fun, I tested the ***pause*** method and found that — at 80 MHz (80,000 ticks per ms) — I got a value of 81,088 for one millisecond. This means that there is an overhead of 1,088 clock ticks for the call. At 80 MHz, this is about 13.6 microseconds. This is the time required to set up the instruction, jump to the ***pause*** method, and then return to the program.

Can we account for this overhead? Sure; knowing the value, we can update the ***pause*** method like this:

```
PUB pause(ms) | t

  t := cnt - 1088
  repeat ms
    waitcnt(t += MS_001)
```

Now, this isn't perfect. A delay of one millisecond comes back at exactly 80,000 counts (okay, that's perfect), but a 1,000 ms delay comes back at 80,000,048 counts. Remember, we are dealing with an interpreted language; I think that a 0.6 microsecond error on an inline delay of one second is probably okay.

TICK TOCK

I mentioned earlier that my friend Wayne was working on a timer project. Originally, we was taking the high and low cycle times — which could be expressed in seconds,

minutes, or hours — and attempting to calculate the number of seconds required for the delay. This caused a couple problems, not the least of which was the opportunity to generate an overflow value on very long cycle times.

A simpler method I proposed was to create a software real-time clock that ran independently of the main program cog. Here's the first version; this one works with values assuming normal clock limits (that is, 60 seconds, 60 minutes, 24 hours):

```
PRI softrtc | t0

  t0 := cnt

  repeat
    if (Clock[REG_RST] < 0)
      longfill(@Clock, 0, 6)
    waitcnt(t0 += MS_001)
    if (++Clock[REG_MS] == 1_000)
      Clock[REG_MS]~
      if (++Clock[REG_SC] == 60)
        Clock[REG_SC]~
        if (++Clock[REG_MN] == 60)
          Clock[REG_MN]~
          if (Clock[REG_HR] == 24)
            Clock[REG_HR]~
            if (Clock[REG_DY] < posx)
              ++Clock[REG_DY]
            else
              Clock[REG_DY]~
```

As you can see, this method works with a global array called *Clock*; the array includes elements for milliseconds, seconds, minutes, hours, days, and a reset flag. That last register is important. Since this method is going to be running in a separate copy of the interpreter — hence operating independently of our main program — we do not want to change the timing registers outside of this method. Doing so could cause a problem where we try to clear the registers while it is half way through an update cycle.

To get around this, we'll use another method. This just sets the flag register which tells the ***softrtc*** method to clear its timing elements:

```
PUB reset

  Clock[REG_RST]~~
```

This method sets the last register to -1. As you can see, the first thing the ***softrtc*** method does is check this value; when it's below zero, all registers (including the reset flag) are cleared to zero in one fell swoop using **LONGFILL**. As the software RTC uses a synchronized one millisecond delay, resetting the clock is reliable and happens within a millisecond.

The code is really quite easy. When we reach 1,000 milliseconds, we clear that register and then add one second. When seconds reaches 60, we clear that register and then add a minute; and so on.

To launch this method into its own interpreter, we'll do this:

```
  cognew(softrtc, @Stack)
```

This form of the **COGNEW** instruction launches another Spin interpreter into a separate cog and points this cog to the ***softrtc*** method. Note that the Spin interpreter needs some stack (RAM) space and, in this case, we're telling the cog to use an array of longs called *Stack*. Setting the size of the stack array can be a little like guessing the weather for next week — you can get close, but until you get there you don't really know.

That stack is used for the storage of local variables, parameters when calling other methods, and intermediate values when evaluating expressions. I tend to set my stack size to 32 longs and have not run into any problems. However, I tend to keep those Spin methods that run in a separate interpreter fairly simple. There is an object included with the Propeller Tool that can be used to check stack size but I tend not to use this as its output is serial. I'd rather do that part myself.

So, I created a really simple object based on an example from a Propeller guru (and very nice, very helpful guy), Phil Pilgrim. Phil's idea is that you can fill your stack with a known pattern and then check the stack — while your program is running — for changes from that pattern. Here are the two methods used in my stack test object:

```
PUB fill(pntr, len)

  longfill(pntr, TEST_VAL, len)


PUB used(pntr, len) | idx

  idx := len - 1

  repeat len
    if (long[pntr][idx] <> TEST_VAL)
      quit
    else
      -idx

  return idx + 1
```

The first method fills the stack with a known test value; this must be done prior to using that stack (or else you will probably crash the program). The second method determines stack usage working from the top to bottom, looking for a change from the test value; when a change is found, **QUIT** is used to terminate the **REPEAT** loop. The syntax of the test line may look a little complicated — it's really not bad. We can access any area of memory using the implicit **long**[] array; that value in the first set of brackets (*pntr*) is the base address of our stack. The value in the second set of brackets (*idx*) is the index into the stack.

I whipped up a little demo (see ***jm_timer_stack.spin*** in the downloads at **www.nutsvolts.com**) to test my stack requirements. Both my stack checker and the Parallax version reported a stack usage of seven longs for the ***softrtc*** method, so the 32 originally allocated was more than enough.

The ***softrtc*** method works great but Wayne pushed back — what he wanted to do is be able to set timing units beyond normal clock boundaries. For example, he might

want to set the on side of the cycle to 90 seconds (in seconds), and have the off side of the cycle set to 210 seconds (total cycle time is 300 seconds; five minutes).

Okay, it's just SMOP (a *small matter of programming*). I copied the ***softrtc*** method and created a new one called ***freerun***. This version is a free-running timer with very little bounds checking:

```
PRI freerun | t0

  t0  := cnt

  repeat
    if (Clock[REG_RST] < 0)
      longfill(@Clock, 0, 6)
    waitcnt(t0 += MS_001)
    if (++Clock[REG_MS] == 1_000)
      Clock[REG_MS]~
      if (Clock[REG_SC] < posx)
        if ((++Clock[REG_SC] // 60) == 0)
          if ((++Clock[REG_MN] // 60) == 0)
            if ((++Clock[REG_HR] // 24) == 0)
              ++Clock[REG_DY]
      else
        Clock[REG_RST]~~
```

This method is structurally similar to ***softrtc*** but we don't do the same bounds checking on the seconds, minutes, and hours registers. We do, of course, check the milliseconds register and treat it the same way. Seconds, however, has a new boundary: **POSX**. This is an internal value that is the largest positive value in the Propeller's 32-bit integer system — it's just a hair over 2.1 billion (the 32nd bit is the sign bit).

The reason for this limit is that we're going to use the modulus operator (//) to check for updates to the other registers when the seconds register changes. Since // treats integers as signed, we have to limit the seconds register to 31 bits. Don't be concerned about this limitation. We could let the timer run for 68 years before the seconds register forces the timer to reset itself.

When I showed Wayne this code, he was happy about the flexibility, but concerned about the accuracy with all that math when value changes are cascading; modulus relies on division which is notoriously slow. I did a quick check using the time tester we played with earlier and determined that even under the worst case conditions — when every register updated on a given cycle — the whole works took about 1/8 of a millisecond. That leaves us plenty of time to get back to and be sitting on the **WAITCNT** for the next 1 ms tick.

I also checked the stack — no change there; still uses just seven longs. After I was happy with the routines, I folded them into an object that I could use in other programs, and adjusted the stack requirement down to 16 (still safe, but not wasteful). You'll find this code in ***jm_softtiming.spin*** of the downloads.

ARE WE DONE?

In early May, I was wrapping up a program for a commercial product and had a situation where I wanted to alert the user of an error condition (using a new variant of my bi-color LED object), but I didn't want it to remain static; after a short period — say two seconds — I wanted the LED to return to the normal program state. As the program is already using several cogs and I wanted to leave the others free for future updates and features, what I needed was a way to kill the error LED without using another cog.

Here's what I came up with: Since my mainline code is running in a loop about every 50 ms, I decided I could just set an error timer and decrement it each time through the loop. Once it reached zero, I would return the LED to the normal state.

To keep things easy, I decided to use milliseconds as my timing unit. This meant I needed a way to determine the elapsed milliseconds since the last check. You know where this is going, right? We've done this with the code timer. Here's the method that returns the number of milliseconds elapsed since some starting point:

```
PUB elapsedms(tstart)

  return ||(cnt - tstart) / MS_001
```

There is a caveat here: the limit (at 80 MHz) is about 26.8 seconds. If we wait longer than that between *tstart* and the call to ***elapsedms***, we'll get a bogus return value (I ran into this the hard way when trying to using this method with another feature in my product).

To use this method, I set up two global variables: *LedT0* and *LedTimer*. The first is set to the system counter to create the *tstart* checkpoint; the second is the number of milliseconds I want the LED to be in the error state.

Here's a bit of code that demonstrates the use of ***elapsedms*** (see ***jm_et_demo.spin***):

```
  repeat
    c := term.rxtime(50)
    if (c => 0)
      LedT0 := cnt

    case c
      "1"   : led.red
              LetTimer := 1_000

      "2"   : led.green
              LetTimer := 2_000

      "3"   : led.yellow
              LetTimer := 3_000

      other : if (c => 0)
                led.set2phase(RED,100,YEL,100)
              LetTimer := 1_000

      ' check led

    if (LedTimer > 0)
      etms := elapsedms(LedT0)
      if (etms < LedTimer)
        LedTimer -= etms
        LedT0 := cnt
      else
        LedTimer := 0
            led.off
```

The **REPEAT** loop will run about every 50 ms if no key is pressed; this is controlled by using the ***rxtime*** method

and setting the timeout value to 50. If a key is pressed (*c* will be greater than or equal to zero), the *LedT0* start point is reset and the key is processed. A valid key gets a solid color; a bogus key causes the LED to flash. For all key events, the LED timer is set accordingly.

The bottom of the loop is what processes the LED timing. When *LedTimer* is greater than 0 (still running), we retrieve the elapsed milliseconds since *LedT0*. If this value is less than *LedTimer*, it is subtracted and the *LedT0* start point is reset. If *etms* is greater than the timer value, the timer and LED state are cleared.

Why did I do it this way instead of simply calling the ***pause*** method for 2,000 milliseconds? Well, my product has several manual inputs, as well as a serial command stream, and I didn't want them to be delayed for an error LED — especially since one of those inputs could correct the condition. Some of you will no doubt point out that this process can result in a timing error of up to 50 milliseconds. You are correct. That said, this is for a visual indicator, so any small variation in the timing will not be a problem. This is a case where imperfect timing took precedence over the use of another cog.

WRAP-UP

Before I close, I want to share one last thing having to do with stacks, though nothing to do with time or timing. Many of us come from Basic where we often use **GOTO** in order to get from place to place in a program. There is no equivalent of **GOTO** in Spin, and this can lead to troubles if we're not aware of it.

For example, I've seen new Spin programmers set up a program like this:

```
PUB main
  ' do something
  method1

PUB method1
  ' do something
  method2

PUB method2
  ' do something
  main
```

While — from the Basic point of view — this seems logical, it creates a serious problem for Spin. You see, when we call a method, Spin expects that we're going to come back and continue at the next line; like an implied **GOSUB**. In the above example, the program will work for a while, but will ultimately go haywire. The reason is that when we call a method, the return address (that is, the address of the line just after the call) is pushed onto the stack. At the end of the called method, we pop that address off the stack and go back. Of course, this all happens "under the hood."

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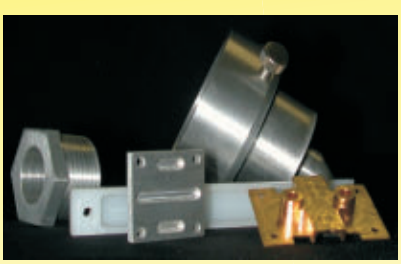

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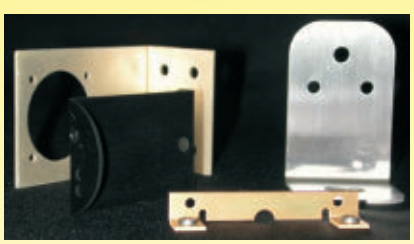

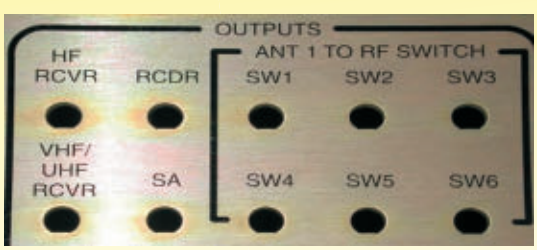

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Well, in the framework above we are calling methods in a continuous loop so the stack can eventually explode, kind-of like Mr. Creosote in Monty Python's *The Meaning of Life* after than final "wafer thin mint." It was funny on screen; it's not funny when it happens in our Propeller programs, and can lead to frustrating debugging sessions.

The fix is easy. Just remember that the call to a method is like a **GOSUB**, and that the program wants to come back when that method is finished. Knowing this, we can re-arrange our ***main*** method as follows:

```
PUB main

  repeat
    ' do something
    method1
    method2
```

... and, of course, remove the calls at the ends of ***method1*** and ***method2***.

I know this is obvious for you seasoned programmers, but having run into this a couple times — usually by those migrating from Basic — I thought it was worth bringing up.

Okay, then, it's time (*yeah, yeah, bad pun*) to get out your Propeller and start working with time-based events. Do spend a bit of time in the manual looking at **LONGMOVE**. You can use this to take a quick snap-shot of your timer registers for timed events, perhaps like a Pinewood Derby timer or similar project (see ***jm_key_timer.spin*** for a simple example).

Until next time, keep spinning and winning with the Propeller. **NV**

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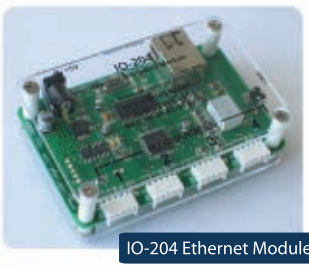

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60/100/200/300MHz 2 ch, 2GS/s DSO 2000 wfm/s refresh rate. High quality, ultra Compact Design with small footprint. Totally new price.
DS1052E $519
• • thru • •
DS1302CA $1995
FreeCase!

microCAM

Compact compressed-serial output camera module for any host system. JPEG OmniVision™ CMOS VGA color camera for embedded imaging.
uCAM TTL or 232 $58

Multiparameter Loggers

Mini-logger with built-in temp/humidity/ pressure/3-axis accel sensors. Customize msmt/record parameters; send data to PC after or during logging. Synchronize multiple loggers.
MSR145S from $527

SPI Bus Analyzer

PC-based SPI protocol exerciser/analyzer for standard/non-standard interfaces <50 Mbps. Monitor serial traffic; test/debug parameters & custom variations for embedded system/IC dev't and validation.
$739

.NET Board

FEZ Domino (Arduino) & **FEZ Mini** (BS2) are tiny open source boards using USBizi chipset: USB host + SD interface, NETMF (.NET). 72Mhz NXP ARM with runtime debug (bkpts, stepping, etc.) Use Visual C#.
Starter Kits $98

EMC Spectrum Analyzers

Handheld Palm PC-based 2.7GHz Spectrum Analyzer. Multiple sweep settings – store wfms, set-ups, etc. Use WiFi PC for email, reports, calculations.
PSA2701T $1989

SOMO-14D

14-pin Tiny Audio-Sound Module plays back pre-stored audio files (voice and music) from micro-SD card - ideal for embedded audio output.
SOMO-14D $25

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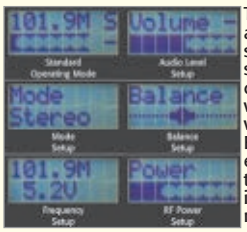
Digital Controlled FM Stereo Transmitters

- ✔ Rock stable PLL synthesized exciter
- ✔ Front panel digital control and display of all parameters!
- ✔ Professional metal case
- ✔ Super audio quality!
- ✔ 25mW kit and 1W export models!

For nearly a decade we've been the leader in hobbyist FM radio transmitters. When it became time for a new model, we started from the ground up! We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters!



The FM30 is designed using through-hole technology and components and is available only as a do-it-yourself kit, with a 25mW output very similar to our FM25 series. Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35WT version, with 1W output for our export-only market! Both are designed around an RF tight vinyl clad metal enclosure for noise free and interference free operation. All settings are done through the front panel digital control and LCD display! All settings are stored in non-volatile memory for future use.

Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC 110/220VAC plug in power supply. The stylish black anodized aluminum case measures 5.55"W x 6.45"D x 1.5"H. and is a great match to your other equipment. *(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)*

FM30B	**Digital FM Stereo Transmitter Kit, 0-25mW**	**$199.95**
FM35BWT	**Export Only Transmitter Assembled, 1W**	**$299.95**

Professional FM Stereo Radio Station

- ✔ Built-in audio mixer!
- ✔ 2 line inputs, auto mic ducking!
- ✔ Dual LED bar graph meters
- ✔ Drift-free PLL synthesized operation
- ✔ Precision brick wall audio filter!
- ✔ 25mW kit and 1W export models!

The true professional workhorse of our FM Stereo transmitter line, the FM100B has become the transmitter of choice for both amateurs and professionals around the world. From the serious hobbyist to churches, drive-in theaters, colleges and schools, it continues to be the leader. Not just a transmitter, the FM100B is a fully functional radio station and provides everything but the audio input and antenna system.

This professional synthesized transmitter is adjustable directly from the front panel with a large LED digital readout of the operating frequency. Just enter the setup mode and set your frequency. Once selected and locked you are assured of a rock stable carrier with zero drift. The power output is continuously adjustable throughout the power range of the model selected. Audio quality is equally impressive. A precision active low-pass brick wall audio filter and peak level limiters give your signal maximum "punch" while preventing overmodulation. Two sets of stereo line level inputs are provided with front panel level control for both. Dual front panel LED bargraph meters provide left and right channel audio level metering. In addition to the line level inputs, there is a separate microphone input with a built-in mic mixer to control the level. Not enough? How about unattended microphone ducking! When enabled, the presence of mic audio automatically reduces and overrides the line level input! Just like the professional units at a fraction of the cost. The FM100B is truly a complete radio station!
(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM100BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)

FM100B	**Super-Pro FM Stereo Radio Station Kit, 5uW-25mW**	**$269.95**
FM100BEX	**High Power Version Kit, 5uW-1Watt Output**	**$349.95**
FM100BWT	**Export Only Transmitter, 5uW-1Watt, Assembled**	**$429.95**

Professional Synthesized Stereo FM Transmitter

- ✔ Fully synthesized 88-108 MHz for drift-free operation!
- ✔ Line level inputs and output!
- ✔ Simple DIP switch frequency setting

Priced like an inexpensive hobby transmitter but performs like a commercial unit! This unit is truly a cut above the rest, which probably explains why it is the most popular hobby transmitter around the world!

The FM25B features a PIC microprocessor for easy frequency programming without the need for lookup tables or complicated formulas! Frequency selection is done with simple DIP switches. The FM25B features a superb stereo generator providing you with amazingly good stereo separation to keep even the pickiest audiophile happy! Kit comes complete with case set, whip antenna, 120 VAC power adapter, & audio cable. SMT parts are factory preassembled! *(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body)*

FM25B	**Professional Synthesized FM Stereo Transmitter Kit**	**$139.95**

Professional Synthesized AM Radio Transmitter

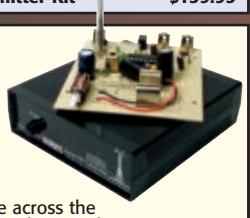
- ✔ Fully frequency synthesized, no frequency drift!
- ✔ Ideal for schools
- ✔ Microprocessor controlled
- ✔ Simple settings

Run your own professional sounding AM "Talk Radio" station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area.

It is widely used by schools - standard output is 100 mW, with range up to ¼ mile, but is jumper settable for higher output where regulations allow. The PLL synthesized frequency is easily set with dip-switches and is rock solid without any drift, just like our FM25B. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply!
(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body)

AM25	**Professional Synthesized AM Radio Transmitter Kit**	**$99.95**

Tunable FM Stereo Transmitter



- ✔ Tunable throughout the FM band, 88-108 MHz!
- ✔ Settable pre-emphasis 50 or 75 µSec for worldwide operation
- ✔ Line level inputs with RCA connectors

The FM10A has plenty of power and is manually tunable across the entire band. The detailed manual covers theory, range, and FCC Rules & Regulations making it a favorite school and Scouting learning kit. Runs on an internal 9V battery, external power from 5 to 15 VDC, or an optional 120 VAC adapter. Learn all about FM stereo broadcasts with this simple kit. Includes matching case!

FM10C	**Tunable FM Stereo Transmitter Kit**	**$44.95**
AC125	**110VAC Power Supply for FM10C**	**$9.95**

Tunable AM Radio Transmitter

- ✔ Tunes the entire 550-1600 KHz AM band!
- ✔ 100 mW output, operates on 9-12 VDC
- ✔ Easy to assemble one evening kit!
- ✔ Line level input with RCA connector

A great first kit, and a really neat AM radio transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! Learn kit building and radio theory and at the same time get on the air with your own "station"! The AM1C has also been used by Scout camps, churches, schools, and other organizations to provide easy, low cost communications at events, meetings and much more. Includes matching case!

AM1C	**Tunable AM Radio Transmitter Kit**	**$34.95**
AC125	**110VAC Power Supply for AM1C**	**$9.95**

Tru-Match FM Broadcast Antenna

We've been besieged with calls asking us where to get a good quality FM Broadcast antenna. Remember, matching your antenna to your transmitter is the single most important link in your transmitter setup - and a good antenna and match are the secret to getting maximum range.

- ✔ Fully weatherproof-rugged PVC construction
- ✔ Matches 50 or 75 ohm systems
- ✔ Tunable for a perfect match over the entire 88-108 MHz FM band
- ✔ 25 watt RF power maximum

When we say "match" we mean electrical impedance match... if the proper impedances are not maintained between transmitter and antenna, power is reflected away from the antenna and back into the transmitter! This can cause the final amplifier stage to be damaged, not to mention spurious signals and lousy range. Don't forget, there are three important factors in your broadcast range: antenna, antenna, and antenna! With the Tru-Match you'll get the most from your FM Broadcaster!

TM100	**Tru-Match FM Broadcast Antenna Kit**	**$69.95**

Vintage Battery Eliminator

Collectors come across some great deals on antique battery-powered radios, but how to power them is a real problem. Many classic radios operated on batteries only, and in many cases a series of three batteries for each radio were required!

The new ABCE1 Battery Eliminator gives you an easy way to replace all these batteries with a simple household AC power connection and resurrect your vintage antique radios! Provides "A" filiment, "B" plate, and "C" control grid supplies, which are all isolated from each other. Complete with aluminum case. Runs on 110-240VAC.

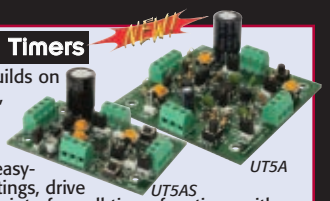
ABCE1 **Vintage Radio Battery Elim Kit** **$199.95**

Digital Message System

The third generation of Ramsey digital voice storage kits! We started with the latest digital voice storage technology. It provides up to 8 minutes of digital storage at a frequency response up to 3.5 KHz. (Total message time and frequency response is dependant on selected internal sampling rate.) Once recorded, messages are available for playback on-demand or automatic continuous looping. Standard RCA unbalanced line level output is provided for easy connection to any amplifier, amplified speaker, mixer, or sound system. In addition, a standard 4-8 ohm speaker output is provided to directly drive a monitor speaker. Can be remote controlled via 3-wire BCD with our interface options. Check www.ramseykits.com for all options!

DVMS8 **Digital Voice Message 8Ch Kit** **$99.95**
DVMS8WT **Assembled DVMS8** **$149.95**

Ultimate 555 Timers



This new series builds on the classic UT5 kit, but takes it to a whole new level! You can configure it on the fly with easy-to-use jumper settings, drive relays, and directly interface all timer functions with onboard controls or external signals.

All connections are easily made though terminal blocks. Plus, we've replaced the ceramic capacitor of other timer kits with a Mylar capacitor which keeps your timings stable over a much wider range of voltages! Available in through hole or surface mount versions! Visit www.ramseykits.com for version details.

UT5A **Through Hole 555 Timer/Osc Kit** **$24.95**
UT5AS **SMT 555 Timer/Osc Kit** **$26.95**

Passive Aircraft Monitor

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

ABM1 **Passive Aircraft Receiver Kit** **$89.95**

Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

VS1 **Voice Switch Kit** **$9.95**

OBDII *CarChip Pro*

The incredible OBDII plug-in monitor that has everyone talking! Once plugged into your vehicle it monitors up to 300 hours of trip data, from speed, braking, acceleration, RPM and a whole lot more. Reads and resets your check engine light, and more!

8226 **CarChip Pro OBDII Monitor-Asmb** **$99.95**

RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 **RF Preamp Kit** **$19.95**

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.

TS1 **Touch Switch Kit** **$9.95**

Doppler Direction Finder

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

DDF1 **Doppler Direction Finder Kit** **$169.95**

Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

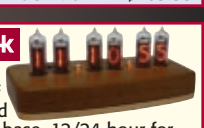
MB1 **Mad Blaster Warble Alarm Kit** **$9.95**

Laser Light Show

Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

LLS1 **Laser Light Show Kit** **$49.95**

Retro Nixie Tube Clock



Genuine Nixie tubes popular in the 50's brought back in one of the neatest digital clocks around today! Hand made teak maple base, 12/24 hour format, soft fade-out, auto-dim, and a crystal time base at 20ppm! Tube kits also available.

IN14TM **Teak Maple Nixie Clock Kit** **$329.95**

Water Sensor Alarm

This little $7 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump)! When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.

MK108 **Water Sensor Alarm Kit** **$6.95**

USB DMX Interface

Control DMX fixtures with your PC via USB! Controls up to 512 DMX channels each with 256 different levels! Uses standard XLR cables. Multiple fixtures can be simply daisy chained. Includes Light Player software for easy control. Runs on USB or 9V power.

K8062 **USB DMX Interface Controller Kit** **$67.95**

HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

PG13 **HV Plasma Generator Kit** **$64.95**

Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

IG7 **Ion Generator Kit** **$64.95**

Tickle-Stick Shocker

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4 **Tickle Stick Kit** **$12.95**

Speedy Speed Radar Gun

Our famous *Speedy* radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. You supply two coffee cans! Runs on 12VDC or our AC125 supply.

SG7 **Speed Radar Gun Kit** **$69.95**

Tri-Field Meter Kit

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.

TFM3C **Tri-Field Meter Kit** **$74.95**

USB Experimenter's Kit

Get hands-on experience developing USB interfaces! 5 digital inputs, 8 digital outputs, 2 analog I/O's! Includes diagnostic software and DLL for use with Windows based systems. The mystery is solved with this kit!

K8055 **USB Experimenter's Kit** **$49.95**

3-In-1 Multifunction Lab

The handiest item for your bench! Includes a RoHS compliant temp controlled soldering station, digital multimeter, and a regulated lab power supply! All in one small unit for your bench! It can't be beat!

LAB1U **3-In1 Multifunction Solder Lab** **$129.95**

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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ **Mystery Component**
- ✓ **Convert DC Meter to AC**
- ✓ **Power Supply**

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. **Send all questions and comments to: Q&A@nutsvolts.com**

NEED A FILTER

Q I'm a digital guy and haven't done any RF or filters. I'm looking for a filter that ONLY passes 300 Hz to 3,000 Hz (or possibly 3,300 Hz). The source is a 600 ohm 1:1 transformer coupled to the phone line through a .047 microfarad. A passive filter is preferred. I just want to see what the signal looks like on my scope.

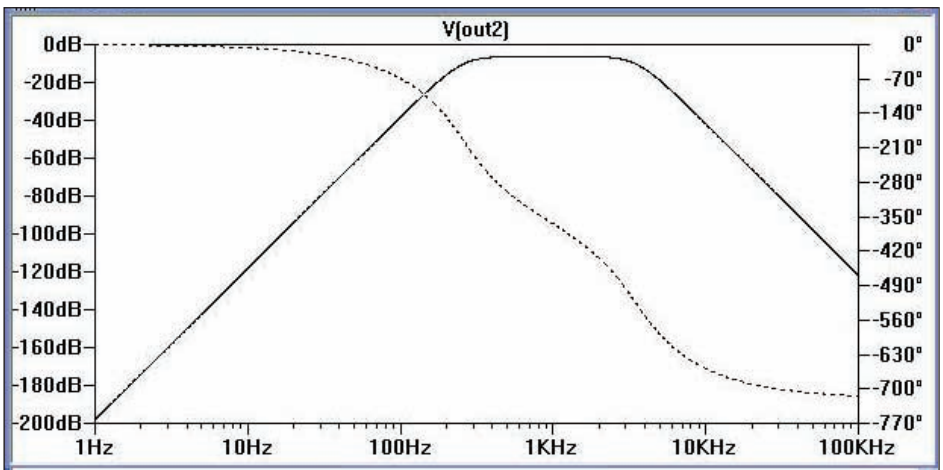
— Toby Norton

A The phone company goes to a lot of trouble to linearize the phase and make voice and data transmit as well as possible. I don't think adding a filter is going to improve anything. That said, I designed an eight pole high-pass and low-pass (bandpass) filter using tables from Philip Geffe's book *Simplified Modern Filter Design*, John F. Rider Publisher. I used the "uniform dissipation networks" table for a four pole Butterworth, d=0.15, but didn't follow the accepted procedure so the result is not perfect. **Figure 2** is the theoretical response with lossless components. In **Figure 3,** I added the transformer and coupling capacitor plus added the coil losses. I didn't add any loss to the capacitors because they are typically low loss. **Figure 3** is not satisfactory so I re-designed it with more bandwidth and increased the coupling capacitor (**Figure 4**). I was curious about the transient response, so I drove the filter with a complex wave form (**Figure 5**). The wide pulse represents 100 Hz and the narrow

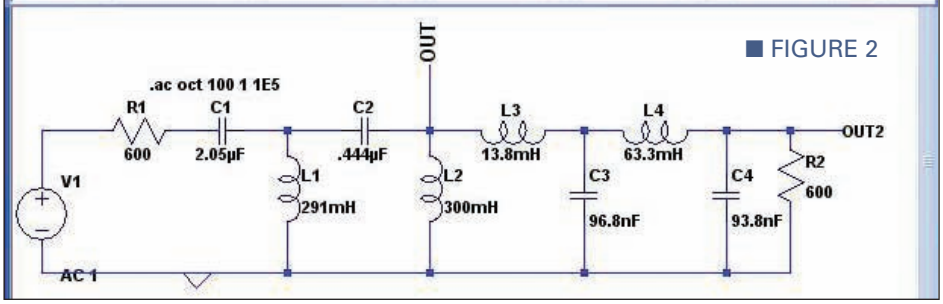
FILTER PARTS LIST ■ FIGURE 1

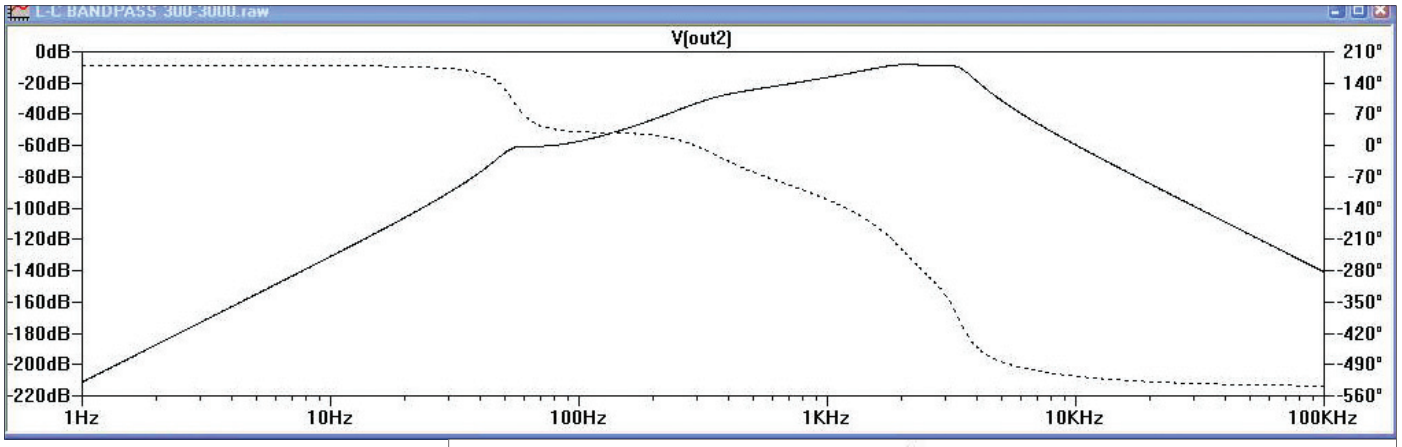
PART	DESCRIPTION	MOUSER PART #	PRICE
C1	1 µF, 50V, 10%	80-C340C105K5R	1.06
C2, C7	.27 µF, 50V, 10%	80-C322C274K5R	0.42
C3, C4	.027 µF, 100V, 5%	80-C330C273J1G	2.17
C5	.47 µF, 100V, 10%	80-C340C474K1R	1.36
C6	1.5 µF, 50V, 10%	80-C340C155K5R	2.61
C8	.033 µF, 50V, 10%	80-C322C333K5R	0.17
C9	.047 µF, 50V, 10%	80-C320C473K5R	0.19
C10	.01 µF, 50V, 10%	80-C322C103K5R	0.13
L1, L2	4 EA 100 mH IN SERIES	43LJ410	1.08
L3	47 mH, 10%	43LJ347	1.08
L4	10 mH, 10%	43LJ310	1.08

THE RESISTORS ARE INTERNAL TO THE COILS.

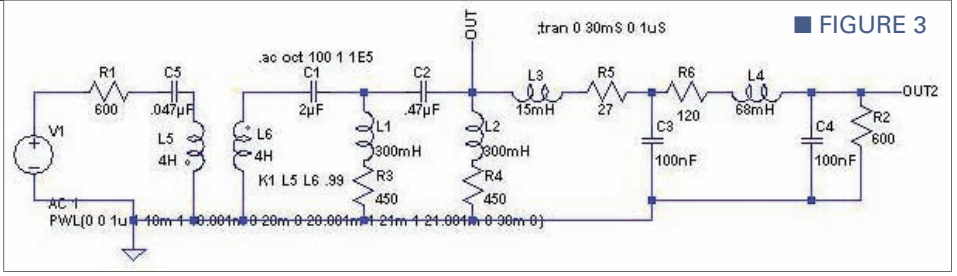


■ FIGURE 2





pulse represents 1 kHz. **Figure 1** is the parts list. More could be done but I think this will provide the information you seek.



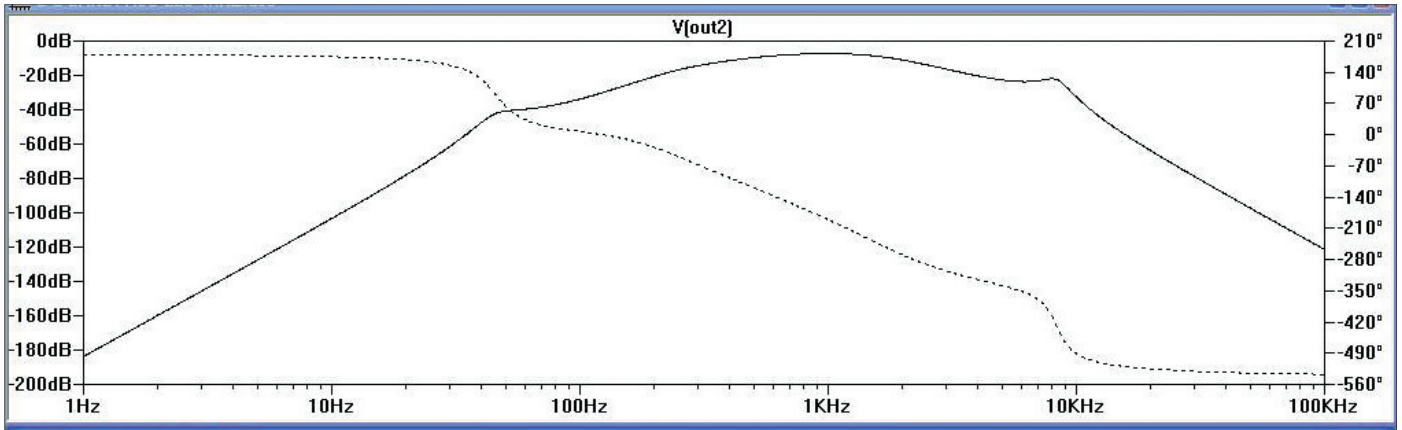
■ FIGURE 3

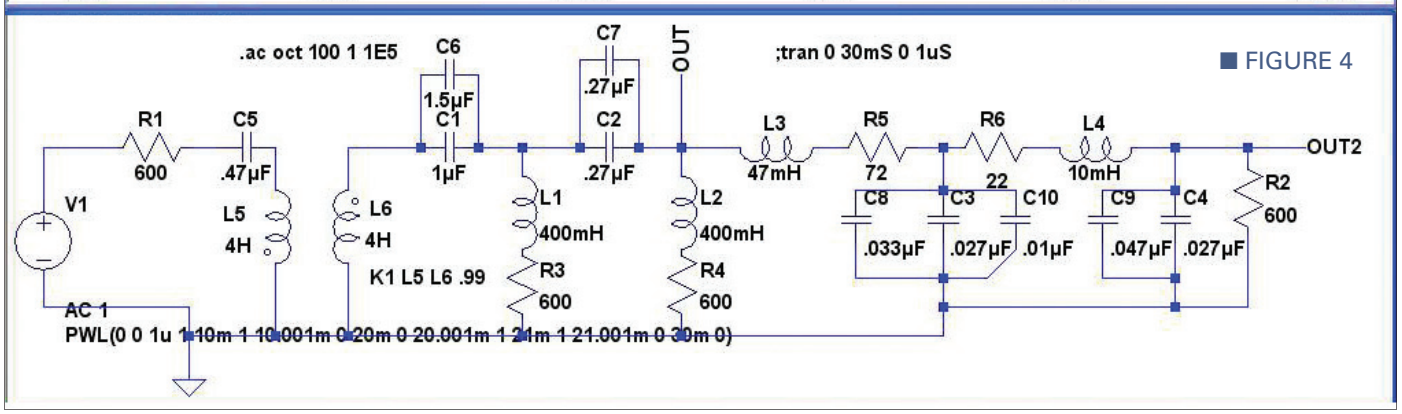
CONVERT DC METER TO AC

Q I have a DC digital panel meter that I want to use to monitor AC line voltage. The meter has a 200 VDC range. I need a circuit that I can use to convert AC to DC.

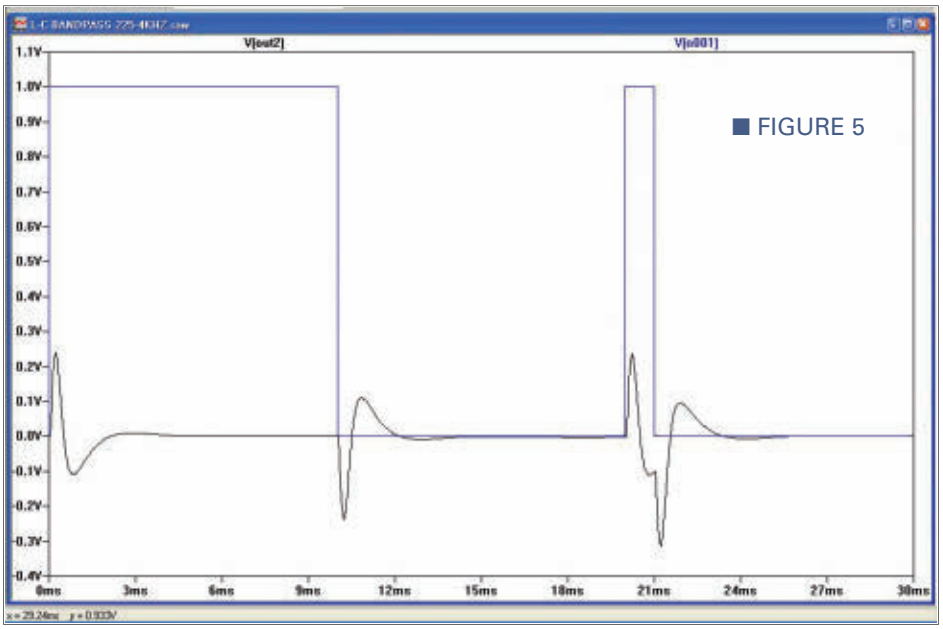
— Ken Bartone

A In **Figure 6**, I used a bridge rectifier in order to double the ripple frequency and minimize the filter capacitor size. If your meter is four digits, the last digit will flicker due to ripple. You can use a larger capacitor if that is a problem. I assumed that your meter resistance is one meg; if it isn't, you will need to change R1 and R2 by the same ratio that the meter varies from one meg. The parts are through hole; these are becoming hard to find. I would have used a DIP-4 package for the bridge rectifier, but couldn't find one.

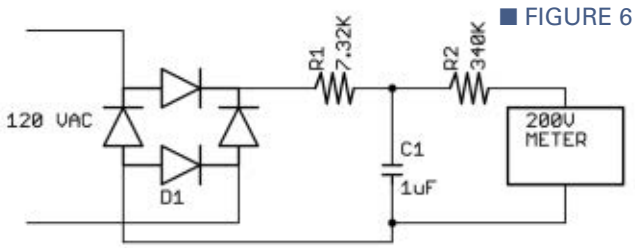




■ FIGURE 4



■ FIGURE 5



■ FIGURE 6

PART	DESCRIPTION	MOUSER PART NUMBER
D1	600V, 4A, BRIDGE	627-LN45B60-7000
R1	7.32K, 1%, 1/4WATT	271-7.32K-RC
R2	340K, 1%, 1/4 WATT	271-340K-RC
C1	1uF, 250 VDC, 10%	75-MKT1822510255

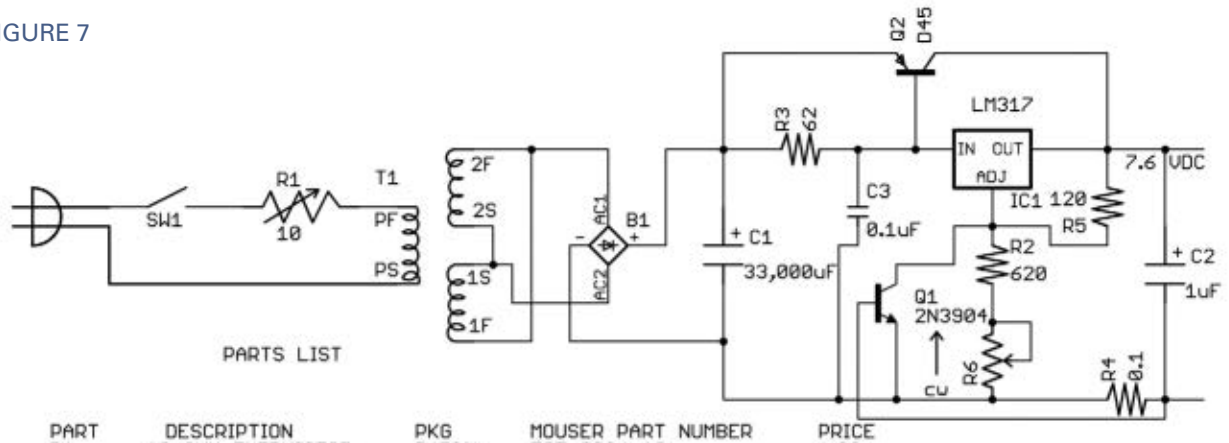
POWER SUPPLY

Q I need a 120 VAC to 7.6 VDC @ 3A regulated power supply, and have been unable to find a schematic to construct such. If you can help, it truly would be appreciated. It will be used to drive 46 double LED strips similar to "Hyperion R-lite Systems."

— Frank Lemon

A The power supply could be designed using a standard transformer, or as a switching supply using a ferrite core. Since I don't know of any source for ferrite cores for hobby use — and RadioShack is pretty much out of the hobby electronics business — I will go with a standard transformer design (see **Figure 7**). Hammond transformer 183J16 has an output when wired in parallel of 8 VRMS at 3.8 amps. The full wave rectified voltage will be about 10 volts which is enough headroom for a 7.6 VDC regulator. The filter cap needs to keep the ripple below one volt so the regulator doesn't run out of headroom. Using the relation: dV = I*dT/C where I = 3A and dT = 8.3mS, I calculate C = 24.9 millifarads = 25,000 µF (minimum). The LM317 is rated at one amp, so a current boost is needed and is provided by Q2. When the LM317 current exceeds 10 mA, Q2 gets turned on to provide the majority of current.

■ FIGURE 7



PARTS LIST

PART	DESCRIPTION	PKG	MOUSER PART NUMBER	PRICE
R1	10 OHM THERMISTOR	RADIAL	527-3004-10	1.02
R2	620, 5%, 1/4W	AXIAL	291-620-RC	0.04
R3	62, 5%, 1/4W	AXIAL	291-62-RC	0.04
R4	0.1 OHM, 5%, 3W	AXIAL	284-ACS5SW-0.1	1.50
R5	120, 5%, 1/4W	AXIAL	291-120-RC	0.04
R6	100 OHM POT, 1/4W	RADIAL	652-3309P-1-101	0.54
T1	120VAC/8VAC/8VAC, 30VA	PC	546-183J16	24.19
B1	50V, 5A	RADIAL	583-BR605	0.84
C1	33,000uF, 25V, LOW ESR	PC	681-EKMH250VNN333MA	5.60
C2	1uF, 16V, TANTALUM	AXIAL	74-173D20V1.0	0.74
C3	0.1uF, 50V, CERAMIC	RADIAL	80-C320C104K5R	0.15
IC1	LM317, 1A, 35V	TO-220	511-LM317T	0.64
Q1	NPN,60V, 500mA	TO-92	610-2N3904	0.10
Q2	PNP, 40V, 15A	TO-220	863-D45VH10G	1.13

Protection against shorts at the load is provided by Q1 and R4. When the load current exceeds five or six amps, the output is pulled down to 1.2 volts. If the current is still excessive, the output will go lower; a short pulling 10 amps at zero volts would be unusual. Resistor R4 is rated three watts, so it would burn up if 10 amps persisted. In the parts list (**Figure 7**), axial means that the leads are in line with the body and you have to bend them to mount in a printed circuit board (PCB) or perf board. Radial indicates that the leads come out one side so bending is not required. PC indicates that the part has pins intended for soldering to a PCB.

TIMER

Q I would like to build a timer to provide a reliable time on period of two hours; I believe I can't use a 555 for this long a period. Can you steer me in the right direction?

— Bill Woods

A What you need is a 555 timer and a count down circuit. Two hours is 120 minutes or 7,200 seconds. My first thought was to decode an eight-bit counter, but eight bits is not enough if the clock is one second (2^8 = 256). I have some 12-bit counters (CD4040B), but this is a ripple counter and has glitches which make decoding unreliable. If I use the last output (see **Figure 8**), the division is 2^12 = 4,096, but the last output goes high after 2,048 clock pulses and completes the cycle after 4,096 clock pulses, so my time delay will be 2048 clock pulses. Dividing 7,200 by 2,048, I get 3.52 seconds for the clock period. Using the equation on the datasheet for the LM555 and choosing C = 10 µF, Ra = 470K, then Rb = 18K. I show a CD4012 dual four input NAND because I had started out planning to decode, but any inverter will do. The counter starts as soon as power is applied and stops after two hours. The output goes high at the end of the time period and stays there until power is removed or the restart switch is momentarily closed. The capacitor, C2, resets the counter on power-up to insure that it starts from zero.

MYSTERY COMPONENT

Q I am working on a Litton microwave oven, model 1508, which contains a transformer which has failed on its power supply board. The transformer was made by Keystone Transformer, Co., Pennsburg, PA and is marked "Catalog No. PTL-1, Part No. TG." The primary is 120 VAC and it has three secondaries with voltages under load of 7.5 VAC, 7.5 VAC, and 23 VAC. Dissection of the transformer reveals a two-terminal component, in series with the primary, approx. 1/4" x 1/2" x 1/8" in size. No markings are visible on it.

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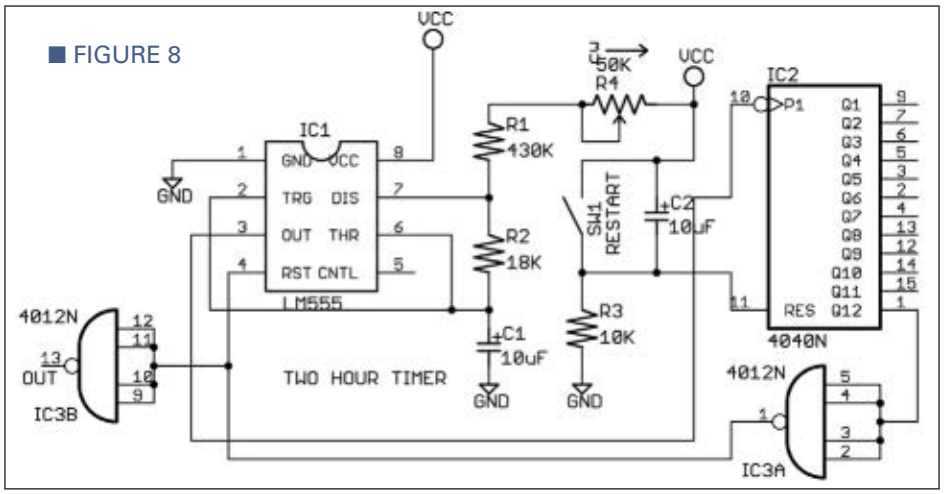
■ FIGURE 8



This component is under the paper wrapping over the windings and is varnished in place; it is not a separate item attached to the transformer externally. Ohmmeter readings show no open windings in the transformer itself; the "mystery component" is open. Bypassing the "mystery component" and applying low voltage to the primary produces secondary voltages appropriate to the reduced primary voltage. My first thought is that this mystery component is some sort of surge suppression device, but not the usual MOV since it is in series with (not parallel with) the primary.

Neither the power supply board nor the transformer are available through my usual parts supply channels. If anyone can tell me either where to obtain a replacement transformer or a new mystery component which could be installed on the existing transformer, it would be greatly appreciated.

— Jon Carter

A The mystery component is probably a positive temperature coefficient thermistor (PTC). It is low resistance at room temperature but at a transition temperature, it switches to a higher resistance. It is no doubt used for overtemperature protection of the transformer. You will find these in most electronics catalogs; most are rated as resetable fuses and intended to be used in open air. The transition temperature may or may not be stated. I found some parts in my Mouser catalog that may be suitable (**www.mouser.com**). If you look up this part number, it will lead you to others: 527-5506-50v5. **NV**

MAILBAG

Dear Russell: Re: April 2010, page 24, Dump Load Calculation.

Another heat dump would be using pipe threaded hot water heaters screwed into a tee with the hot output going to the top of a car radiator from a junk yard and returning from the bottom (cooled) port of the radiator to the heater. Some radiators are the same width as window fans.

I used a pumped setup on a chemical reactor condensate system that was heated by 200 kw and the cooling water never got above 30 deg C.

— Lloyd Peterson

In a back issue of *NV,* there was a dummy load constructed with metal banding steel. Mounted with ceramic posts and a fan, you can build whatever size and resistance you need.

— Brian Nelson

For the 120 amp load, how about modifying an electric heater, the kind with nichrome heating element coils? If you cut the coils into 10 pieces and rewire them in parallel, you'd make a 12 volt load with ten times the amp rating of the original heater. If you can, leave the coils in the original heater for a safe way to mount the hot coils.

If the heater has a fan, it could be replaced with a 12 volt unit, or possibly run from an inverter.

— Corky Mork

Another option would be to stop in at a local (not dealer) car repair shop and ask for used high/low headlamps with one filament burned out (they'd probably be glad to GIVE them to you, just to get rid of them). I think they take around five or so amps each, just parallel enough to draw 120 amps. You wouldn't need any kind of fan or heatsink.

— Mark Peterson

Dear Russell: Re: March 2010, page 29, Soldering Iron Timer.

I have two methods that I have used to turn off my soldering iron when I forget.

The first uses a programmable timer of the type that is designed to turn on a lamp once or twice a day to make a house look lived-in when everyone is away. This timer uses a synchronous motor that runs continuously and makes one revolution per day. A switch is pushed by moveable pins that allow the setting of the on and off times.

The timer is rewired so that the motor runs only when the switch is on. In operation, the programming pins are set for one hour between on and off. The timer is plugged into an outlet, the soldering iron is plugged into the timer, and the dial is rotated by hand until the on pin turns the switch on. The timer motor and the soldering iron will both be on for one hour until the off pin hits the switch. At this point, the motor will not run until the dial is again rotated to on.

The on time can be set for up to almost 24 hours for other applications. I have used modified timers for my wife's electric iron (which I have a tendency to leave on) and a battery charger that won't stay on forever if I forget to check.

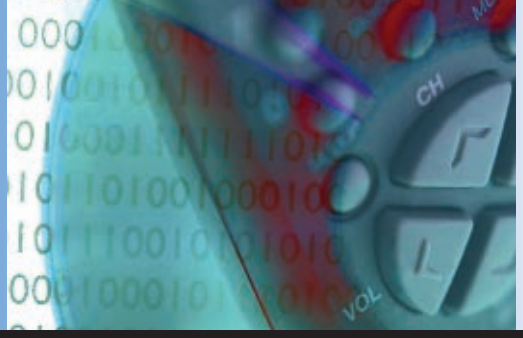
Choose a synchronous timer that can be taken apart.

The second method has the soldering iron plugged into the shop light circuit so that when I leave and turn off the lights, the iron is turned off. In retrospect, one could use the light circuit with a 115 VAC relay that needs a pushbutton to turn on and latches through a normally open contact. This contact would also apply power to the soldering iron. Then when the lights are turned off, the relay and soldering iron turn off and stay off.

— Dave Nellis

A much simpler solution would be using a 60 minute auto off wall switch. These are commonly used in bathrooms to automatically control a heater or exhaust fan.

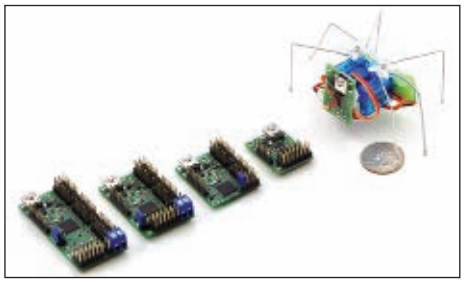
— Tim Naami



NEW PRODUCTS

- HARDWARE
- SOFTWARE
- GADGETS
- TOOLS

MAESTRO USB SERVO CONTROLLERS



Pololu has released the Mini Maestro 12-, 18-, and 24-channel USB servo controllers. In addition to a TTL serial interface, these small boards incorporate native USB control for easy connection to a PC and programmability via a simple scripting language for self-contained, host controller-free applications. The Maestros' extremely precise, 0.25 us resolution servo pulses have a jitter of less than 200 ns, making these servo controllers well suited for high-performance applications; individual speed and acceleration control for each channel allow for smooth, seamless movements. The Mini Maestros feature configurable pulse rates up to 333 Hz and can generate a wide range of pulse widths to allow maximum responsiveness and range from modern servos. Units can be daisy-chained with additional Pololu servo and motor controllers on a single serial line. A free configuration and control program is available for Windows and Linux, making it simple to configure and test the board over USB, create sequences of servo movements for animatronics or walking robots, and write, step through, and run scripts stored in the servo controller. The 8 KB of internal script memory allows storage of up to approximately 3,000 servo positions that can be automatically played back without any computer or external microcontroller connected. Unit prices are $29.95, $39.95, and $49.95 for the Mini Maestro 12, 18, and 24, respectively.

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continued on page 77

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BY CORBIN ADKINS

BUILD THE SELF-LOCKING BOX

A few months ago, I saw an article on an Arduino blog site that showed a project that included a GPS sensor, an LCD display, a servo, and an Arduino board. It had a button on top that when pressed would turn on the circuit, which would then check the GPS signal and display the results on an LCD. It was concealed in a nice wooden box that locked itself with a servo motor. The premise was that it would only unlock if you reached a certain global location, making it what the builder called a "reverse geo-cache" box. I saw that and got inspired to make my own self-locking box, just not activated by GPS. I only wanted to use what I had lying around — and I didn't have a GPS module at the time. I did have the Parallax RFID reader sitting in my parts box and realized it would be perfect to use. So, I built my own RFID-controlled self-locking box. I'll show you how to do the same. First, here's an introduction to RFID and an overview of the project.

Introduction to RFID

(For a more in-depth study of RFID, see the links provided in the **Resources** box.) RFID stands for "Radio Frequency Identification" and the technology is used in more places than you may think. It is used in supermarkets, toll booths, farms, and airports.

There are three types of RFID tags: battery, passive, and battery aided. The battery type is powered by a battery, providing good range at the cost of battery life. This one isn't used a lot in the consumer market. The passive type gets its power from a signal, but has a short range. This is the most common type, since it is useful, as well as cheap. Battery aided tags use a battery for power, providing greater range than the passive type. Power from the signal is used to "wake up" the device so the battery power is not constantly being consumed. (This is the kind used in toll booths for "drive-through" payments.)

This project will use the passive type. We don't need (or want) long range, so it will work great. The RFID reader located inside the device (reading the tags) sends out signals set to the frequency of the tags, and then receives an ID number assigned to each tag. The ID number is stored in ROM inside the RFID tag and is transmitted after receiving the signal. The signal powers the RFID tag with an electromagnet. In the same sense, power is turned into a magnetic field; a magnetic field can then be turned into power.

The magnetic field is produced by the RFID reader with the same antenna used for picking up the return signal. The electromagnetic field then inducts a current in the antenna for transmitting. Once the power is received by the tag, a small microprocessor reads the ROM and transmits the ID code. This is why it's short range; a reader would have to be huge in order to produce a large enough magnetic field. The RFID reader module then processes the code and sends it to the microprocessor.

Hardware Overview

Parallax is my choice for microcontrollers, so I used a Propeller. I also used a Parallax serial LCD for a display and a Futuba continuous rotation servo to control the lock, which is a pistol type with a long metal "rope." The

servo is simply glued to the key. The wooden box is approximately 10 x 14 inches at the base. The top is a "treasure chest" style and slants on the front and back sides. I mounted the display where I took a board out so it faces you; the power switch is located beside the LCD and controls power to the Propeller protoboard. This is shown in the opening **photo**.

The removed board is replaced by sheet metal that has holes drilled in it for the components. The servo is secured at the bottom by two strips of sheet metal and hot glue. The lock is secured in the same way, with the upper strip of sheet metal coming out of the edge of the box. This may not be the most secure fashion, but it worked for me. The protoboard is secured with screws and the RFID module is secured with hot glue.

I like to constantly modify and upgrade my projects, so the circuits are all built on a breadboard that is fastened to the protoboard. The protoboard has female headers soldered to the pins for easy access. The RFID reader is plugged into the breadboard and a serial connection made with the Propeller chip. The servo and serial LCD are connected with headers straight to the protoboard, as well.

Software Overview

The software is super simple so it can be adapted and modified easily. It is written entirely in SPIN — the native high level language of the Propeller (as opposed to the native low level language PASM) — and takes advantage of

How to Build It

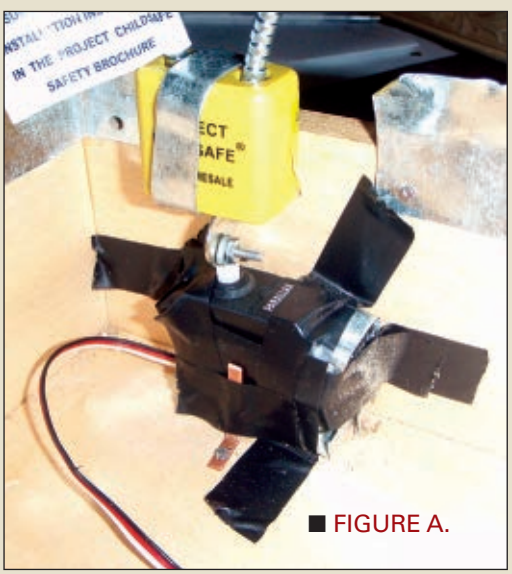
1. Find a wooden or plastic box that has a hinged lid. If you use a metal box, you will need to either mount the RFID reader on the outside or cut a hole so that the metal is not in the path of the RFID signal. You will need some sheet metal, Plexiglas, or acrylic to secure the lock and controls to.

2. Get a "rope" type pistol lock. Since the circuits on the top of the box make it heavy, the rope on the lock helps keep it from tipping over.

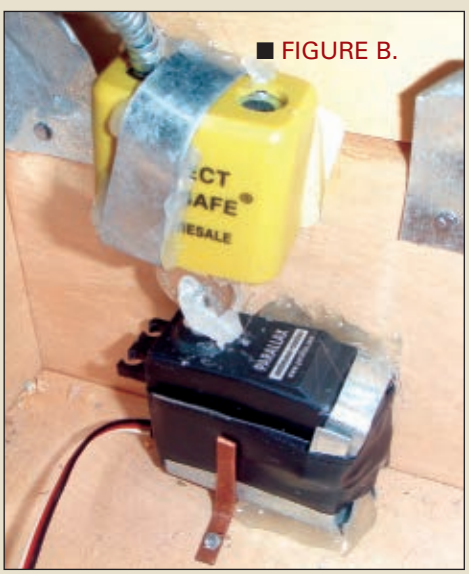
3. With the key in the lock, place it in the box to make sure it fits. The top of the lock should be level with the edge of the box. I taped everything down while I secured the servo to the key (see **Figure A**). I then screwed a small "loop" screw into the servo and ran a screw through the loop in the lock and the loop screw. (Look at **Figure A** again to see what I mean.) I glued down the servo and the key and servo joint. **Figure B** shows the completed locking mechanism. I did use a strip of metal over the top of the lock to prevent the lid from being strained so hard that it pulls the lock right off the servo.

4. Solder or assemble the circuit on a breadboard. On the RFID reader, connect VDD to 3.3V and VSS to ground (marked VSS on the board). Connect the "\EN" (Enable) to P1 and "SOUT" to P0. Connect the "5V" to the 5V line on the LCD. (This can be found right below the power regulator to the far right.) Connect the ground to VSS and the signal line to P8. Connect the red wire to 5V on the servo, and the black wire to VSS. You should place a resistor between the servo control pin and P4. Since the Propeller is a 3.3V device, there could be certain voltage spikes that might damage the microcontroller. (This is a precaution that can be omitted if you are using a chip with a rating of 5V or more.) Connect the pushbutton with one end to VDD and the other to P16.

5. Drill holes in the lid of the box and fasten the circuit board with screws. If you are using plastic, use machine screws. If you use wood screws, cut the end off to avoid injury. The Propeller code can be found on the *NV* website at **www.nutsvolts.com,** as well as additional photos of my completed box. You will have to edit the code at the end to comply with your RFID card codes. (See instructions in the Testing section on where to get this.)



■ FIGURE A.


■ FIGURE B.

6. Remove the top from the hinges if possible. If not, then be sure to measure carefully. Line up the end of the rope (from the lock) with the newly secured lock. Make sure the notched side lines up with the hole in the lock. Fasten this down with whatever you like. (I went with "U" nails used in roofing and bent nails to hold it in place.) Make sure it fits properly before moving on. (See the top right corner of **Figure C.**)

7. Cut the positive wire on the battery holder at midpoint. The positive has a white stripe;

the Propeller's multi-processor capability. It consists of the "Debug LCD" object and the "servoEngine" object. Both objects are run in separate cogs (processors) and can be operated independently and/or simultaneously. The way the software works is that the program launches the objects and then checks for a button press. It then displays on the LCD "Lockdown in 10 seconds." It counts down and if the button is not pressed in 10 seconds, the servo moves 90 degrees (for continuous rotation, this took a lot of trial and error). The box is then locked and the device must be reset to use the RFID card. To turn the device on and off, you (obviously) use the power switch on the front.

When the button is pressed, the LCD displays "Lockdown Cancelled" and the Propeller switches to the RFID scan loop. The RFID code is from a demo posted in the Propeller Object Exchange but has been modified to fit the needs of this project. The one notable part of the program is the small section in between a servo on and a servo off command:

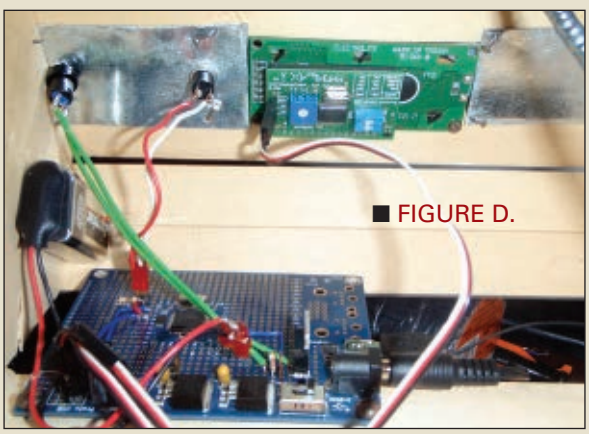
```
Waitcnt ((clkfreq/20)*4 + cnt)
```

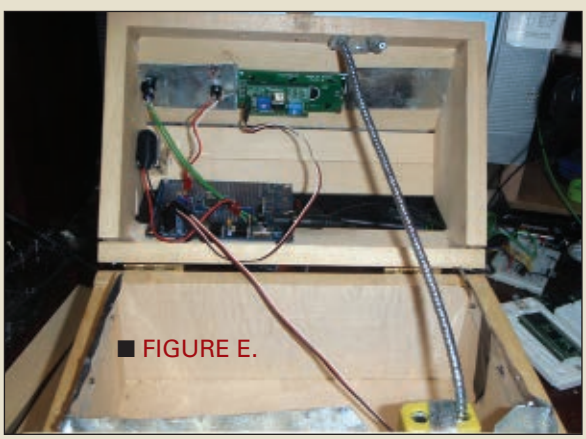
This line is for repositioning the servo after startup. Upon startup, the servo would give a little "twitch" caused from the sudden spike of the power supply. The servo didn't turn more than two degrees, but it was enough to lock the box (locking because it was always twitching clockwise). This waiting period (also a matter of trial and error) was designed to twitch the servo back into its

leave the negative intact. Strip and tin the wires. Separate the positive and negative wires, and pull them apart so they're easier to work with. Connect the positive from the battery side to one of the contacts on the SPST switch. Solder the positive wire from the barrel connector to the other contact on the SPST switch. Plug the barrel connector into the board. For a permanent solution, solder the wires directly to the board. See **Figure D** and **Figure E** for a view of the connections.

8. Drill and cut holes for the LCD, the button, and the switch, and insert the components. You're now ready for testing.

■ FIGURE C.


■ FIGURE D.


■ FIGURE E.

BILL OF MATERIALS

QTY	DESCRIPITION
1	Wooden box
1	Pistol lock and key
1	Servo
1	RFID reader (serial)
1	LCD 2x20 backlit
1	14" LCD extension cable
2	Three-pin header
1	Propeller protoboard (USB or not, doesn't matter)
10	Three inch wires
1	Normally open pushbutton
1	10K resistor
1	SPDT switch
About 12" of wire	
12" x 12" sheet of sheet metal	
Hot glue	
(Optional) a breadboard and four 10-pin female headers	

RESOURCES

A board and pre-programmed microcontroller will be available soon at **www.gadgetgangster.com.**

The Arduino blog that inspired this: **http://arduinia na.org/projects/the-reverse-geo-cache-puzzle**.

For more information on RFID technology, check out these links: **http://electronics.howstuffworks.com/gadgets/high-tech-gadgets/rfid.htm** and **http://en.wikipedia.org/wiki/Radio-frequency_identification.**

Corbin Adkins
microcontrolled@gmail.com

original position. I found that for my servo, 4/20 of a second was the perfect time for a twitch correction.

Testing

Turn on your box with the outside switch. You should hear the servo, and the screen should light up. If this doesn't happen, open the box and check the power light. If the power light is not on, check your wiring around the switch circuit and (I know this sounds crazy, but it could happen) check to make sure the batteries are inserted correctly. If the light is NOT on, then turn the power off and check for a short circuit. If the light is on, then check the servo/LCD connections. If it starts up with no problems, let the second counter run down to zero. You should have the box closed and you should hear the servo. If you hear the servo but the box is not locked, check the position of the lock and servo, and make sure they are well secured. The problem may be that the notched bar on top is not going all the way into the

Tips and Mods

• If the servo doesn't fit underneath the lock, you will need a taller box. I didn't have this option and my lock stuck up above the edge about 3/4 inches. I took the board I removed from off the top (to insert the controls) and used it to raise the edge up so the lock was hidden. I used sheet metal on the inside to cover up the sides so that someone couldn't reach in and take the contents. The box didn't close exactly right, but it worked.

• If you are planning to put the circuits in the bottom of the box and connect the RFID reader to the top, you'll need to take the inductance of the wires into consideration. I tried to use a four wire, 12 inch cable from a computer to connect the RFID reader, but it didn't work. The middle cables were twisted, causing unwanted inductance and cross talk among the serial lines. If you want to extend the distance of the wires, you will have to use a serial line driver/extender (like the Maxim line of serial drivers — the MAX2323).

• During construction, you should keep the RFID reader's header as close to the chip's pins as possible for minimum inductance and noise. You will also need a three-pin wire to go from the serial LCD to your microcontroller unless you plan

lock. You'll need to move it in this case.

If the RFID doesn't work, check the connections and make sure no metal is blocking the signal. If you are using the protoboard, make sure that you change one of the tag numbers that are represented at the bottom of the program to match your own tag. Otherwise, it will not work. Use the object here to get the tag number: **http://obex.parallax.com/objects/332/**.

After changing the pins to comply with the ones you are using, run the program on the Propeller chip. You will have to remove the Access Granted/Access Denied section of the code so the RFID code will show on the display. If you have any other trouble with construction/coding issues, feel free to email me.

If it works fine, then great! I would suggest putting the RFID tag in a wallet or under a watch like I did. Then, you can just swipe your arm or wallet across the surface of the box to have it unlock. Have fun! **NV**

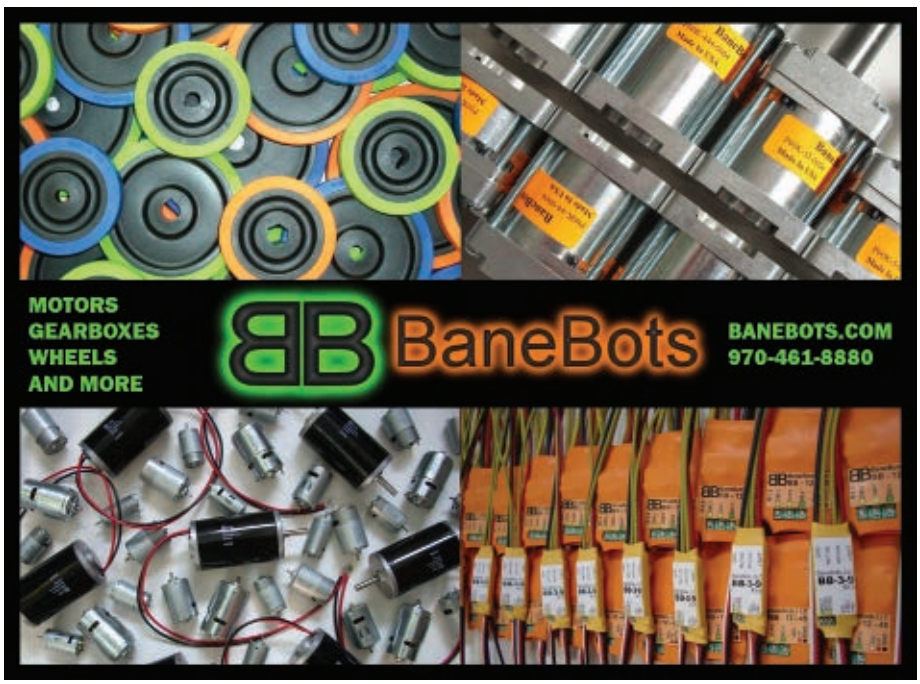
on soldering the board to the bottom of the LCD. This is not recommended, however.

• If there's a fault in your LCD or board, you won't be able to remove the LCD very easily. So, before you solder, make sure that the components fit. Also, the RFID reader MUST be facing out. If the RFID reader fits over the top of the circuit board and faces down into the box, it will not work properly. Remember that RFID readers are blocked by anything metal (EMI suppressant). This means that the circuit board you are using will block the signals. The RFID reader should hang over the side of the board. If the box is too short for this, have the RFID reader on the bottom of the board and mount it about 3/4 inches off the underside of the lid.

• Remember if sheet metal is used, keep it out of the path of the RFID reader. The RFID reader must not be more than 1-1/2 in (3 cm) away from the scanning area, since the type of reader we are using here has a maximum scanning distance of 2-1/2 in (5 cm).

• If you are using your own micro and/or writing your own program, use a standard servo. A continuous rotation was all I had, so I made do.

• Check for project updates at **http://designedbymemicros.blogspot.com/**. I hope you enjoy it as much as I do.



WIRELESS TRAILER TAILLIGHTS

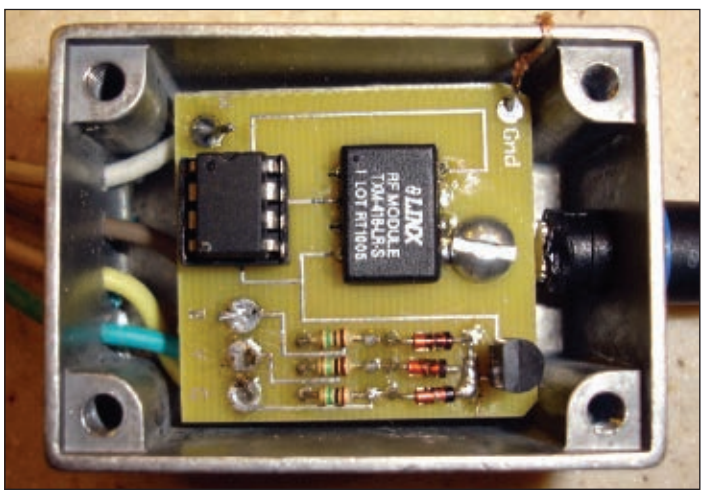
BY RON NEWTON

A friend of mine needed help solving a problem his local construction firm was having with his big gravel trailers and water tankers. His employees kept breaking the taillights and/or ripping out the towing harnesses. This caused a sizable amount of down time and expense due to repairs. As you know, it is illegal to tow without taillights, and my friend's rigs are big. It is a disaster waiting to happen if wiring harnesses are being flexed too much.

LEDS draw small amounts of energy and can be powered using small batteries for long periods of time. That makes them ideal for this type of project.

The unit presented here can be installed in minutes and can also be carried for emergency taillights in the event the wires are ripped from the trailer.

This project does involve a small amount of surface soldering and chassis drilling. A Microchip programmer is a plus, however, programmed chips and the PCBs are available from the *Nuts & Volts* webstore. (I highly recommend ordering these boards directly from *NV*.) The board files are also on the *Nuts & Volts* website (**www.nutsvolts.com**). You will need to cut the board (a shear works best). The cost of the parts is about $80 in addition to the boards. This may sound a little on the expensive side, but considering the cost and installation of wired taillights — especially if you have several trailers — it's a bargain.



■ FIGURE 1. Transmitter Board.

Meet the Transmitter

The transmitter is powered when you plug in the car or truck trailer connector. When the lights, brakes, or flashers are turned on, their power is used to transmit. The taillights are powered by two D batteries which should last about 100 hours with the lights on. Most trucks and cars come prewired with a trailer connector; the standard is a flat four wire connector with the designations shown below. Adapters are available for other types.

FOUR WIRE CONNECTOR
1. White wire is ground.

2. Brown wire is general headlights (taillights).
3. Yellow wire is left turn and stop.
4. Green wire is right turn and stop.

The transmitter sends codes to the receivers which decode the signals and turn on the LEDS. The range of the transmitter/receivers is about 300 ft.

The transmitter consists of a microcontroller, transmitter, three diodes, three resistors, a voltage regulator, and two capacitors. Each trailer connector wire provides 12 volts when switched. Diodes are connected to each wire and their cathodes are connected together. The diodes prevent the return of current to the other wires. A three volt linear voltage regulator is used to reduce the voltage to the ICs. The large 470 capacitor stores just enough energy to transmit an off signal when the lights are turned off. The 10 µF capacitor filters the output of the voltage regulator.

With three lines, there is a possible combination of six states ($2^3 = 6$). The 12F508 decodes which wires are hot and converts this into the first three bits of a byte. The micro is programmed to produce a serial data output of 16 bits. This allows $2^{13} = 8{,}192$ transmitter combinations.

The first key of the combination is the first byte. The second key uses the last five bits of the second byte (the first three bits being the wire codes). The bytes are transmitted using a 16-bit asynchronous serial stream with a stop and start byte. This data is fed into IC2 and transmitted. The data is transmitted at 1200 baud.

To keep in compliance with FCC regulations, the "lights are on" signal only transmits once every 10 seconds when the lights are turned on. The brake and turn signals transmit when needed. This keeps the transmission rate to a minimum.

The Linx Technologies TXM-433-LR transmitter module that I'm using here (see **Parts List**) only needs an antenna and does not require any other external components to transmit. However, the antenna and chip do need a ground plane (which both the board and chassis provide).

Meet the Receiver

The receiver acquires the signals and passes the data to the 12F508 which decodes the serial data. All three micros must be coded with the same keys as the transmitter for the system to work. Two bytes are extracted from the serial data. The first byte and part of the second byte is checked to see if the key is identical. If this data matches, it decodes the last three bits which determine what the taillights do.

The Linx Technologies RXM-418-LR receiver was constantly being bombarded with noise and gave me fits as I kept getting random turn on and off action. I took care of this by adding a piece of code in the software which insures that the signal is high for a period of time before it starts decoding the data.

The taillights have two rings of LEDS. The outer ring is for the taillights; the inter ring is for the brake or turn signals. Only two signals need to be deciphered per unit. The signal for the opposite unit is ignored. The receiver chips are coded for left and right turn signals.

The LED rings are controlled by two NPN transistors. Two D batteries power both IC1 and IC2. Each transistor has a voltage drop of .8 volts. This allows the LEDS to be driven at 2.2 volts 20 milliamps each. The ground plane acts as a reflector.

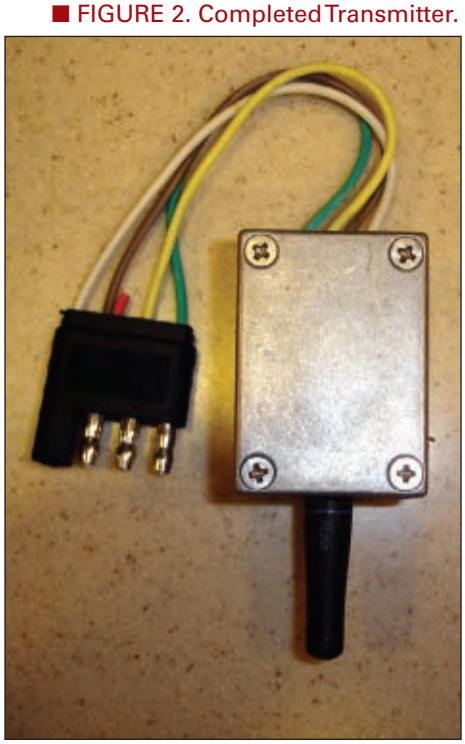
I have included an RSSI (received signal strength indicator) pad for those who want to troubleshoot or check the power of the transmitted signal. (See the RXM-418-LR specification sheet for further information.)

The software is programmed so that if no signals are received within a one minute period (lights on), it will turn off the LEDS.

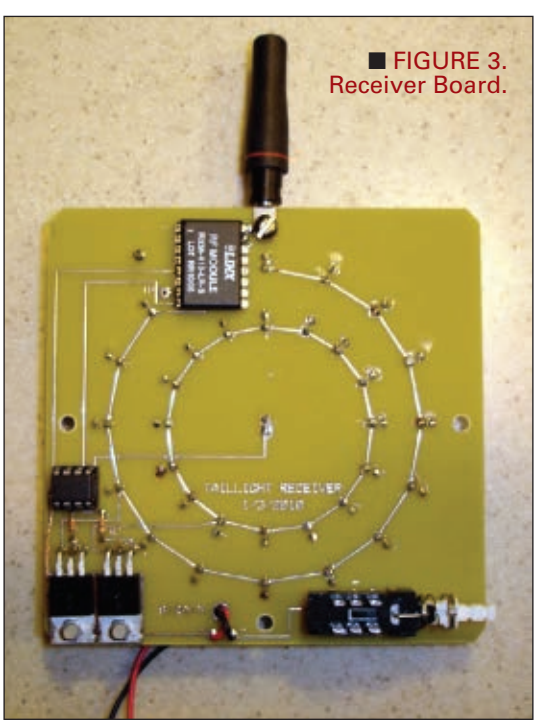
Construction Time

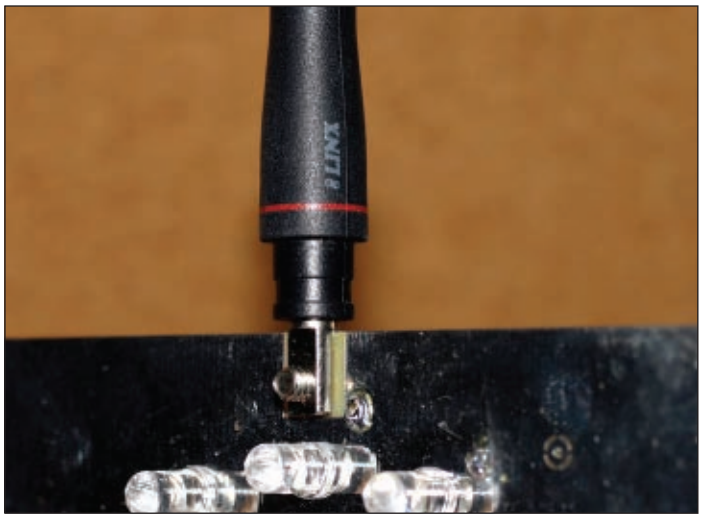
On the *Nuts & Volts* website, there are two assembly files. You will need MPLAB and a programmer for the chips. For the transmitter, solder IC1 and IC2 to the top side of the board. Solder the three resistors, three diodes

■ FIGURE 2. Completed Transmitter.



■ FIGURE 3. Receiver Board.





■ FIGURE 4. Close-up of antenna's flat area on the LED side of the board.

(note polarity), and the voltage regulator. Solder a piece of 1/2″ solder braid to the hole marked Gnd. Solder the 10 µF cap. Turn over the board and solder the 470 uF capacitor to the bottom side of the board (noting its polarity). There is a file called Trailer Template on the website. Cut out the templates and glue (using glue stick) them to the small transmitter aluminum box. Drill the antenna hole using a 5/16″ drill. Drill four 1/8″ holes for the wires. Remove the templates with hot water.

Starting left to right, push white, brown, yellow, and green wires through the chassis; solder them to the board. Push the antenna through the chassis and secure it to the board using its screw. When securing the lid, pull the solder braid over the lip of the box to ground the box.

For the receiver, solder IC1 and IC2 to the board noting pin one. Solder the two resistors and the switch. Bend the wires of the transistors where the leads thicken, bending them backwards at a right angle. Secure them with 6-32 screws and nuts, and solder them in place. Place the 33 LEDS on the other side. The long leads go to the square pads. Solder from the top side. Run the battery holder wires though the strain hole and solder the red to positive and the black to negative.

Using the template (from the website), glue it to the 4″ square of plastic lens. Drill four 9/64″ mounting holes through the lens. Glue another template to the box; drill five 9/64″ holes (including the center hole). Secure the chassis in a vise and using the center hole for a guide, drill a 3.25″ hole using a fly cutter. You may have to sand or file the corners a small amount on both the plastic lens and the board to make them fit.

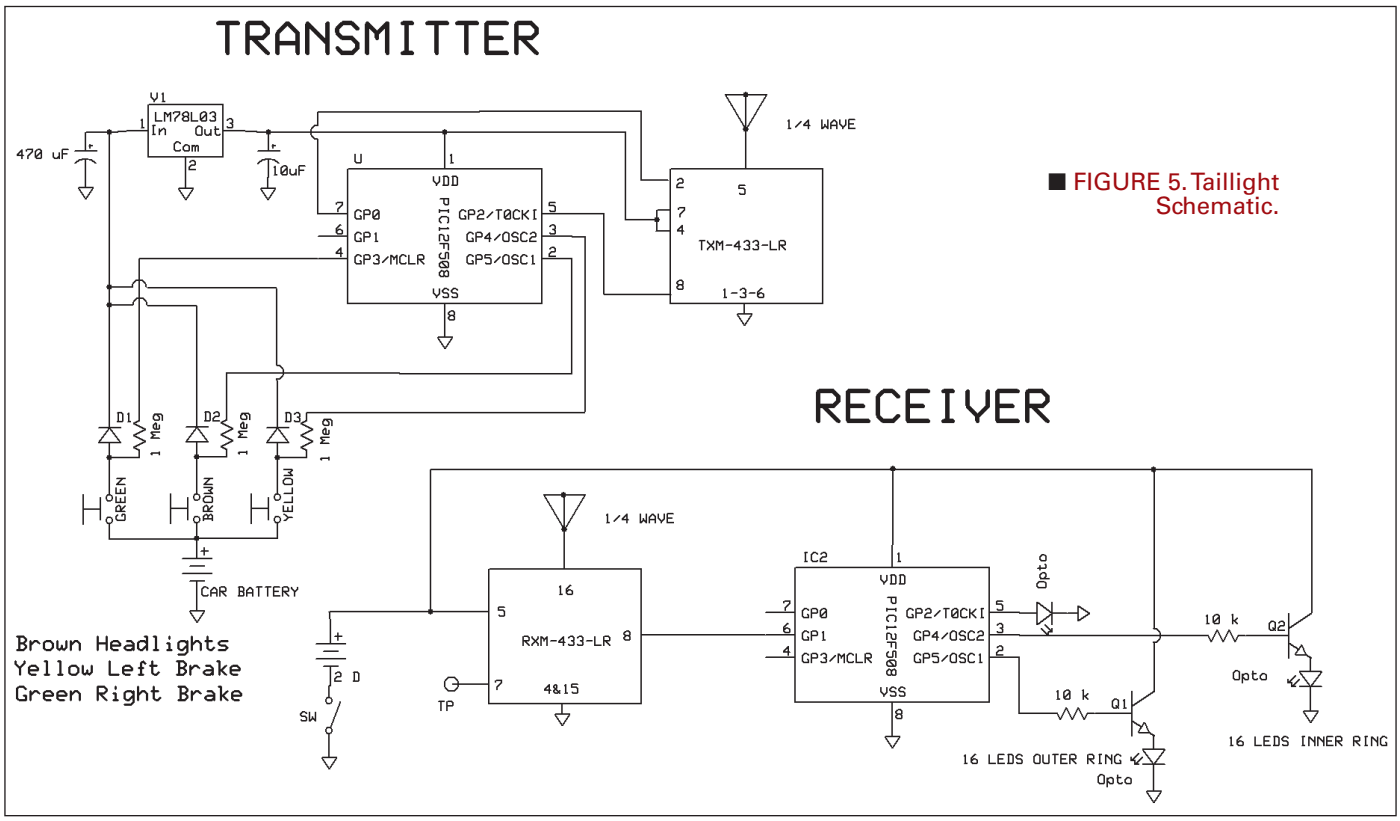
To determine which is the top of the box and which side the switch hole is on, place the board with the LEDS toward the 3.25″ hole noting the mounting hole locations. Glue the antenna template to the top of the box and the switch hole template to the side of the box (where the switch is). Remove the board. Drill a 5/16″ hole for the antenna and 1/4″ hole for the switch plug. I used three #8 eye bolts for bungee cord mounting: two on the sides and one on the bottom. I cut them to shorten the length. Use two nuts on each eye bolt. **Do not** use an eye bolt next to the antenna. Drill three 3/16″ holes in the center of the sides and bottom. Do not add the eye bolts at this time.

Put a small bead of silicone glue around the inside of the 3.25″ hole in the box. Mount the Plexiglas to the inside of the box using one 6-32 screw where the antenna will be. Use three each of 3/4″ 6-32 screws for the remaining holes. Add the 3/8″ standoffs. The board holes will self-thread or you can secure the board to the chassis using three 6-32 nuts. Once tightened, use fingernail polish to secure the nuts. Add a small amount of silicone glue around the antenna. Push the antenna through the hole and fasten with its screw. Its flat area should be on the LED side of the board (**Figure 4**). Add the plug to the switch hole. Drill two holes in the lid to hold the battery box; secure the battery box either with screws or pop rivet.

PARTS LIST

ITEM	QTY	DESCRIPTION	MANUFACTURER /PART #
TRANSMITTER			
Antenna	1	418 MHz 1/4	**LinxTechnologies.com**
Cable	1	Four connector male	
C1	1	470 µF 16 V	
C2	1	10 µF 16 V	
Chassis	1	Aluminum 2.7″x1.5″	Hammond 1590WH
D1-3	3	1n914	
IC 1	1	PIC12f508	Microchip
IC2	1	TXM-418	Linx Technologies
R1-2-3	3	1 Meg 1/8W	
VR1	1	LP2950ACZ-3.0	
RECEIVERS			
Antennas	2	418 MHz 1/4	Linx Technologies
Holder	2	Two D	
Chassis	2	4″ x 4″ x 2	Hammond 1591USBK
Eye Bolts	6	#8	
IC1	2	PIC12F508	Microchip
IC2	2	RXM-418-LR	Linx Technologies
Optos	66	Super Bright Red	
Lens	2	4″ x 4″ x 1/8″ Plexiglas	
Plug	2	1/4″	
Q1-2	4	TIP31A	
R1-R2	4	10K 1/8W	
S&N	2	6/32 1/4″	
S&N	6	6/32 3/4″	
Standoff	6	3/8″ #6	
S1	2	F2UEE	C&K Components

For more info on parts and sources for this project go to the *Nuts & Volts* website (**www.nutsvolts.com**).



■ FIGURE 5. Taillight Schematic.

Now you can mount the eye bolts. Secure the nuts with nail polish. The box I used is water resistant. It should do fine in rain, snow, and mud. However, I would not submerge the unit in water (e.g., a boat trailer). See "Hints and Tips" on the *N&V* website for a submergible unit.

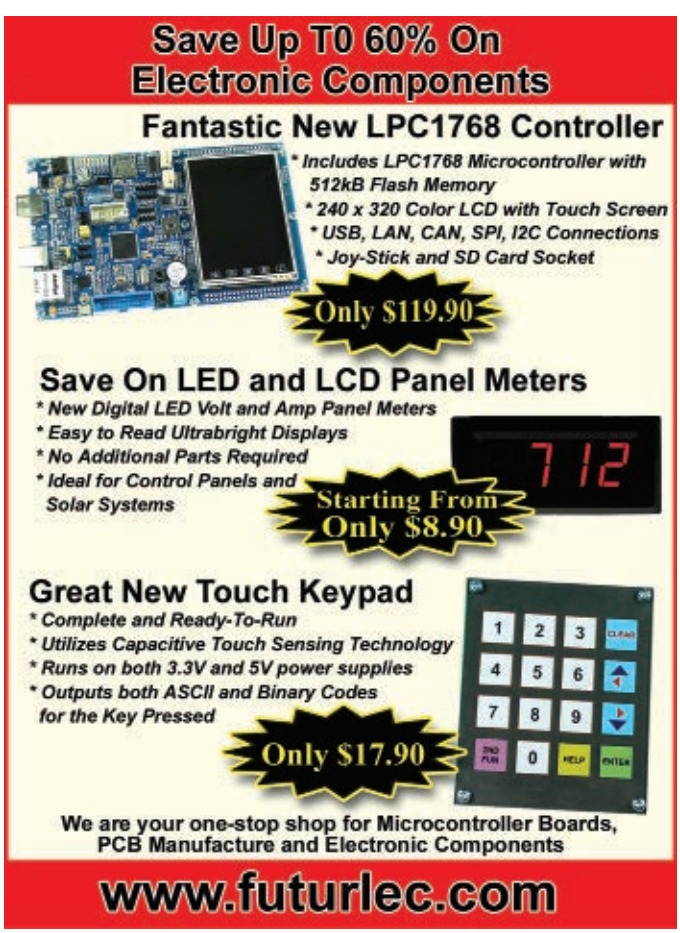
Add two D batteries to each battery holder and secure the lids. You are now in business! When you turn on the switch, the center LED will light for about one second indicating that you have battery power.

Testing the Units

Plug the transmitter into the trailer power connector. Bring both units into the cab and turn on. Turn on the key and step on the brake; both unit's inner ring should light. Turn on the right turn signal; the right taillight should flash. Mark the box on the back with an "R." Turn on the left turn signal; the left taillight should flash. Mark the box on the back with an "L." Turn on the headlights; both outer rings should light.

Using It

You can mount the taillights using small bungee cords or hang them upside down from the bottom eye bolt. Make sure the taillights are on their appropriate side. Plug the transmitter in the trailer connector. For best reception, make sure the transmitter antenna and the receiver antennas are in the same plane. ALWAYS TEST THE UNITS BEFORE TRAVELING. Happy trails (and towing!) to you. **NV**



Experiments with Alternative Energy

Part 12 - Build the Telematics Car

By John Gavlik, WA6ZOK

Telematics is the twenty-first century word for "telemetry" which was coined somewhere around the mid-1950s, to mean wirelessly transmitting data from one point to another — usually from a moving vehicle like a car, plane, or spacecraft to a ground station. These days, telematics is an entire industry generally focused on modern automobiles that wish to be "always connected" to where they are and where they are going. GM's OnStar™ is one example, as is FordSYNC™ that purport to keep you in touch with your vehicle as you drive — as well as the environment in which you're driving — with things like GPS voice activation, accident detection, directions to the next filling station or restaurant, etc.

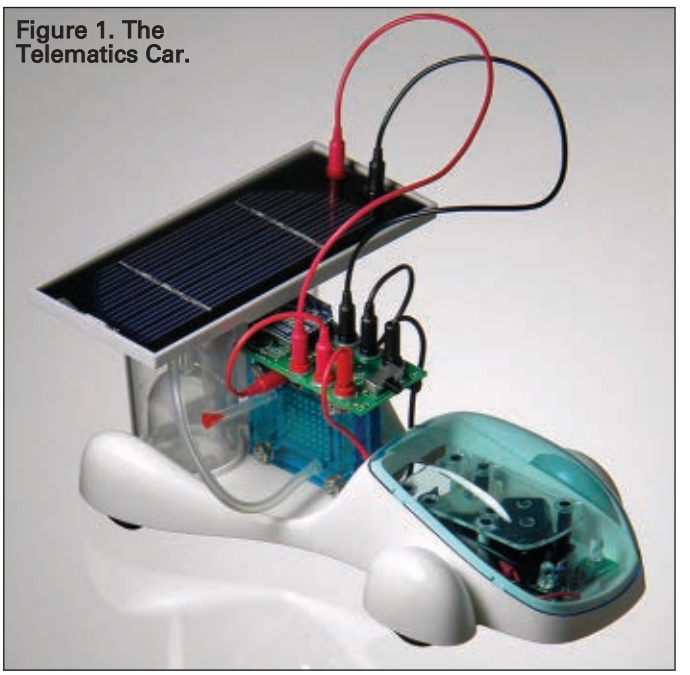


Figure 1. The Telematics Car.

So, what does any of this have to do with fuel cells? The answer is that we are about to equip our [already spectacular] fuel cell powered Hydrocar with telematics capabilities. That is, we will equip it so that it wirelessly transmits the Hydrocar's electric motor parameters to your computer as it moves; this will include [the measure of] the voltage, current, motor resistance, and power wirelessly transmitted in real time to your computer. That way, you can see exactly how the car's motor and fuel cell react when it starts, stops, moves forward, reverse, and up hills and down. Our telematics circuitry will transform a toy into an intelligent teaching tool (**Figure 1**).

ZigBee® and XBEE®

To do this, we will employ a relatively new and powerful wireless technology called ZigBee (formally known as IEEE 802.15.4) that does the hard work of taking in RS-232 type serial data in one module mounted on the car and wirelessly sending it to a receiving module connected to your computer — all without interference and special protocols that are the norm with standard RF methods (like some of the popular 400 MHz and 900 MHz radios). To make matters even better, companies like Digi International (formally Maxstream) have created plug-in modules they call XBEE that contain the ZigBee circuitry plus an antenna. Just add +3.3 volts and a connection to the RS-232 source and you're in business (see **sidebar**).

That's what we'll use for our telematics car plus some embedded microcontroller circuitry that measures the voltage and current drawn from the fuel cell to power the car's motor.

Our telematics system comes in two parts: the transmitter board (**Figure 2**) and the receiver board (**Figure 3**).

The transmitter is a combination of the XBEE radio along with a PIC with 10-bit A/D inputs and other circuitry that sense the voltage and current going into the Hydrocar's electric motor via the fuel cell that powers it. As you can see, the

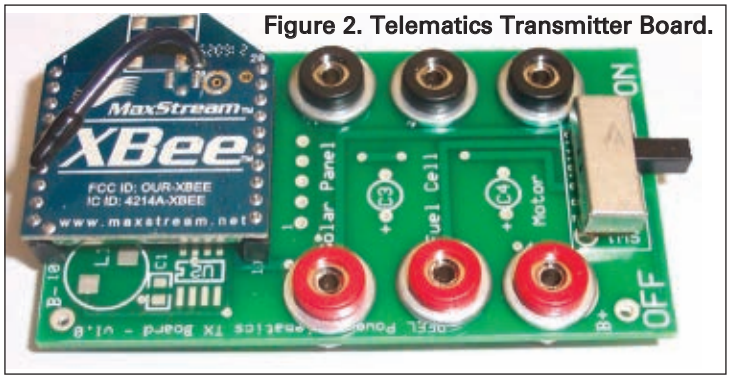


Figure 2. Telematics Transmitter Board.

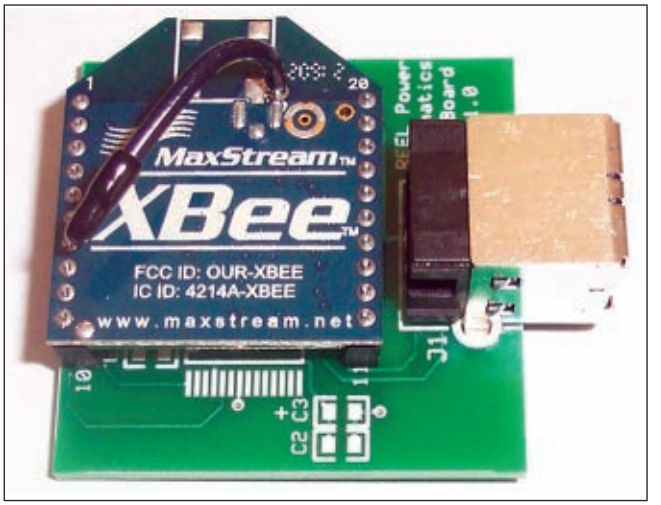


Figure 3. Telematics Receiver Board.

transmitter unit mounts on the Hydrocar's reversible fuel cell and has terminals that attach to the fuel cell, the solar panel, and the motor. There is also an ON-OFF switch that controls both the electrolysis function of the fuel cell (OFF), as well as switching over to power the transmitter electronics and motor after enough hydrogen has been created (ON). When the switch is OFF, voltage from the solar panel flows into the reversible fuel cell to allow the water to be split into hydrogen and oxygen (**Figure 4**). Substitute a three volt battery for the solar panel if you want the electrolysis process to go faster.

When enough hydrogen is generated, switching to the ON position cuts out the solar panel to the fuel cell connection and cuts in the fuel cell connection to the motor. It also applies power from a standard 1.5 AAA battery to power the transmitter electronics. The 1.5 volts is stepped up to 3.3 volts with an onboard DC-to-DC converter circuit. I'm also testing two 1.5 Farad super capacitors in parallel (C3 and C4) to replace the 1.5 volt AAA battery, but my test results are not ready at this time.

I designed the transmitter board with separate terminals for the solar panel, fuel cell, and motor to eliminate all the time-consuming and confusing hookups that come with applying the solar panel to the fuel cell for electrolysis, then tearing this down to hook it up to the motor, etc. One ON-OFF switch does it all for you, and you're off and running doing the experiments in no time.

The receiver is simply another XBEE radio connected to an FTDI serial-to-USB chip that, in turn, is connected to the computer with a USB cable (**Figure 5**). Data from the Hydrocar's transmitter is received and sent to the REEL Power software where all the electrical parameters are plotted as we shall see next.

Experimenting with the Telematics Car

If you've ever wanted to "really know" what kind of electrical performance a model car expends while it rolls across the floor and up and down ramps, the telematics car will show you. I think you'll be both surprised and amazed at what happens — even if our Hydrocar doesn't do wheelies. So, let's start at the beginning by preparing to electrolyze some water into hydrogen fuel for our reversible fuel cell. Fill both cylinders to the 20 ml mark with distilled water and remember to correctly hydrate the fuel cell.

Install the transmitter board on the Hydrocar's reversible fuel cell and hook up the solar panel, fuel cell, and motor leads, and set the ON-OFF switch to OFF (**Figure 6**). While the solar panel (or three volt battery if you wish, instead) electrolyzes water into hydrogen and oxygen, connect

ZigBee

ZigBee — or officially IEEE 802.15.4 — is a low-cost, low-power, wireless mesh networking proprietary standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications, and the low power usage allows longer life with smaller batteries. The mesh networking provides high reliability and larger range. The ZigBee Alliance is an association of companies working together to enable reliable, cost-effective, low-power, wirelessly networked, monitoring and control products based on an open global standard. The most popular applications include:

- Home Automation
- ZigBee Smart Energy 1.0/2.0
- Commercial Building Automation
- Telecommunication Applications
- Personal, Home, and Hospital Care
- Toys

ZigBee operates in the industrial, scientific, and medical (ISM) radio bands; 868 MHz in Europe, 915 MHz in the USA and Australia, and 2.4 GHz in most jurisdictions worldwide. The technology is intended to be simpler and less expensive than Bluetooth. ZigBee chip vendors typically sell integrated radios and microcontrollers with between 60K and 128K Flash memory. Radios are also available as stand-alone to be used with any processor or microcontroller.

Credit: Wikipedia and Digi International, Inc.

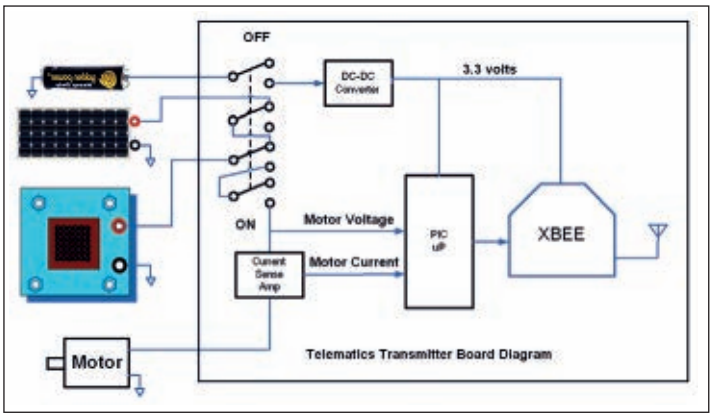


Figure 4. Telematics Transmitter Board Diagram.

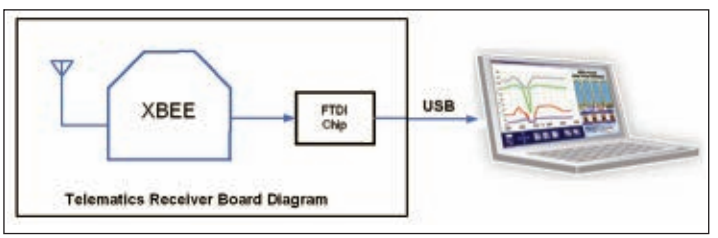


Figure 5. Telematics Receiver Board Diagram.

the receiver board to your computer with the supplied USB cable. With the REEL Power software running, you should see a plot like **Figure 7** as the fuel cell electrolyzes water. While this is happening, elevate the wheels of the car so that they can spin freely once power is applied to the motor. We'll first do some tests with the motor "unloaded" or not powering the car across the floor.

Next, set the switch to ON and see if you experience a plot as in **Figure 8** where the wheels are free-spinning. The jagged black line is the motor's internal resistance which normally varies between two and three ohms. The green line is the fuel cell voltage along with the fuel cell current (blue line) going into the motor load. The red line is the power being produced by the fuel cell into the motor load. Even though the motor resistance is nothing more than a direct result of the voltage and current going to the motor from the fuel cell, I want to emphasize the resistance plot line as it best exemplifies what's happening to the voltage and current on a somewhat exaggerated basis.

Figure 8 shows the motor as it just started up running. Next, place your finger on the car wheels to slow them down in order to create more mechanical resistance and notice how the plot changes (**Figure 9**). The motor's resistance (black line) falls sharply indicating a heavier load for the fuel cell which responds, in turn, by briefly attempting to increase the current output (blue line). However, the load is so great when the wheels stop spinning that the fuel cell's output power cannot overcome the lower resistance of the motor caused by the static resistance. I gave the wheels a slight spin to get them running again which accounts for the rise in voltage, current, power, and resistance at the end of the plot.

What these plots show is the dynamics of the motor's resistance as it reacts to a load. I wanted to show you this before we actually put the car "in gear" and let it run on the floor. In **Figure 8**, the jagged black line shows the motor free wheeling, but the wheels themselves produce mechanical resistance as they spin which causes the motor's internal resistance to react accordingly. The result is not a smooth but jagged black line that has a period in tune with the spinning wheels. We can assume that the wheels themselves are not perfectly balanced which is why the resistance changes as they spin.

The motor needs to expend slightly more or less energy to spin the unbalanced wheels on every rotation thus producing what is shown on the plot. This makes a good case for keeping your automobile wheels balanced as even the slightest imbalance will not only give you a rougher ride and produce premature tire wear; it also uses more fuel despite the smoothing effects of a car's flywheel momentum.

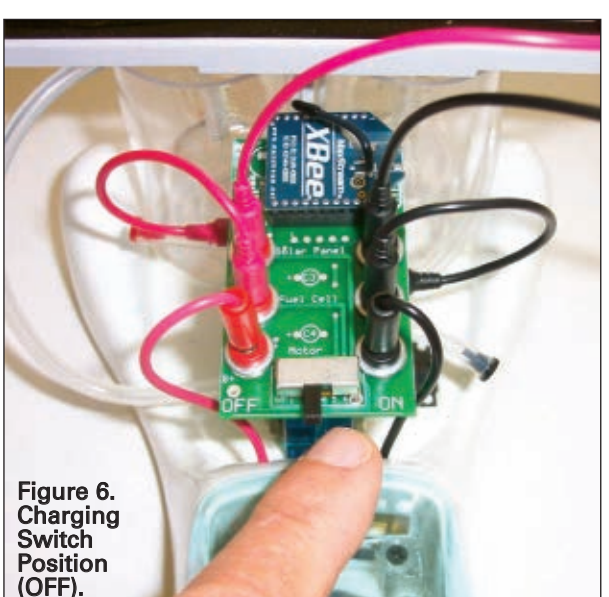


Figure 6. Charging Switch Position (OFF).

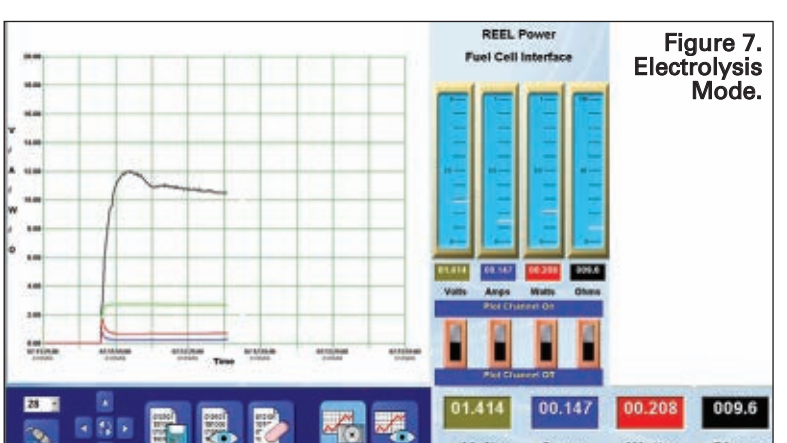


Figure 7. Electrolysis Mode.

Telematics

The availability of telematics-enabled cars has risen dramatically over the past few years. Today, telematics is either standard or optional equipment in most high-end vehicles and the list of features is growing. Telematics covers a wide area of technologies so it's hard to pin down exactly what it is, since it can be many things to many users and equipment producers.

Telematics systems allow a driver to interact with the vehicle in his or her own voice. So, if you are driving in an unfamiliar area you may ask your car to find the shortest route to your destination. Within seconds, a navigation system reads back the directions. This is now standard with vehicle navigation systems but was only a dream 10 years ago.

Telematics can be quite useful during emergency situations. The moment a safety measure is detected in a car — like when the check engine light goes on — the telematics system sends a message to the operator who then calls the car to confirm the safety of the passengers. In case there is a problem, the operator sends help. The GPS unit tells the operator where to send the police and ambulance. If you have forgotten your keys inside the car and the doors have been locked, the telematics system can unlock it for you. This is currently what OnStar™ offers.

The future of telematics looks bright and ominous at the same time. Voice-based web access is certainly a possibility, as well as road-side Wi-Fi systems where commercial businesses can detect if your car is near their retail location and then send you advertisement messages on your cell phone or car navigation screen for what they're selling. Your car can even transmit information like its make and model, where you came from, and where you're going to anyone who wants to know. This "having others know a lot about you while you drive" feature may be the most expansive and yet controversial part of our always connected future. Who knows where it will lead and what implications it will have for individuals and society. Credit: **www.wizgeek.com** and **www.onstar.com**.

Starting, Stopping, and Reversing Direction

The Hydrocar has a built-in stop and turn mechanism that automatically turns the wheels and backs up when the car hits an obstacle. This makes it easier to see what happens to motor fundamentals in a start and stop scenario. Placing the car on a level floor or table will show what happens. Generate some more hydrogen, then place the car on the floor and set the switch to ON. In my test, I set the switch to ON before I put it on the floor. Then, I let the car move and hit a barrier where it stopped, reversed direction, and started out in a different direction. **Figure 10** shows a plot of this activity. Notice that the motor resistance (black line) starts out at a relatively high resistance as the wheels are free spinning, then the resistance drops and current (blue line) and power (red line) increase as it touches the floor and begins to move. The resistance really drops when it hits a barrier and stops. As it reverses, less of a load is placed on the motor and the cycle repeats as it moves and hits other barriers.

Climbing and Descending a Ramp

Another test I did was running the car up and down a slight ramp (not too steep – about 15° is my estimate). To do this, you have to put a piece of tape on the rotating mechanism to hold the wheels in place (**Figure 11**). When you do this, make sure to first empty the cylinders of water so they don't spill all over the floor. Next, refill the cylinders with 20 ml of water and generate some hydrogen again. Place the car at the bottom of the ramp and turn the switch ON. **Figure 12** shows a plot of the car as it moves up the ramp. Notice that the resistance drops below one ohm, indicating that more power is required to move the car up the ramp as compared with just

Figure 8. Wheels Free-Spinning.

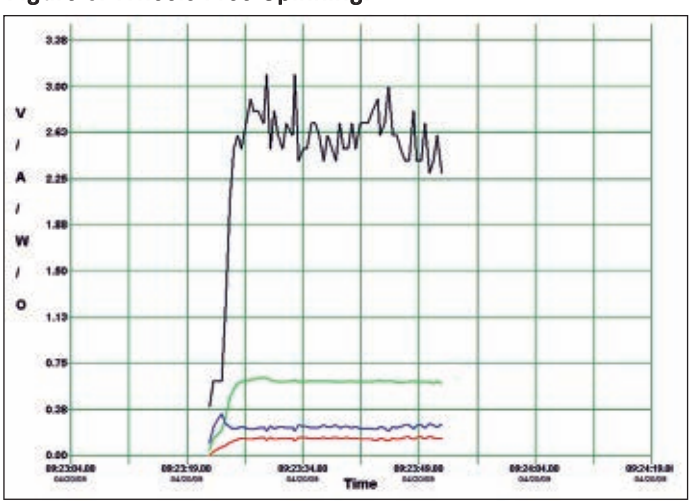
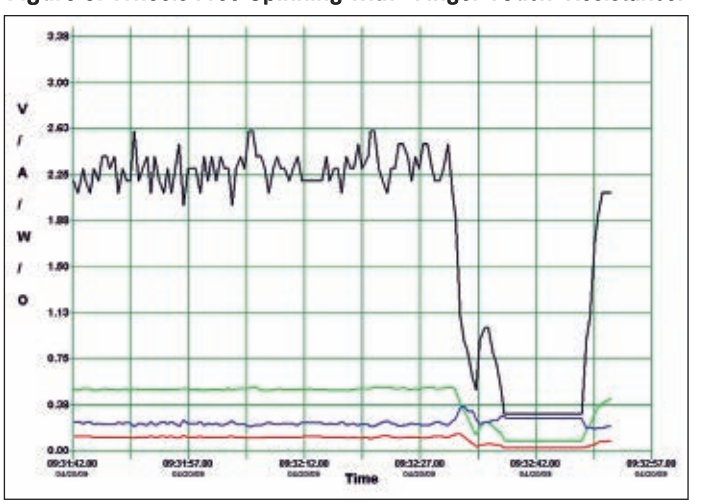


Figure 9. Wheels Free-Spinning with "Finger Touch' Resistance.



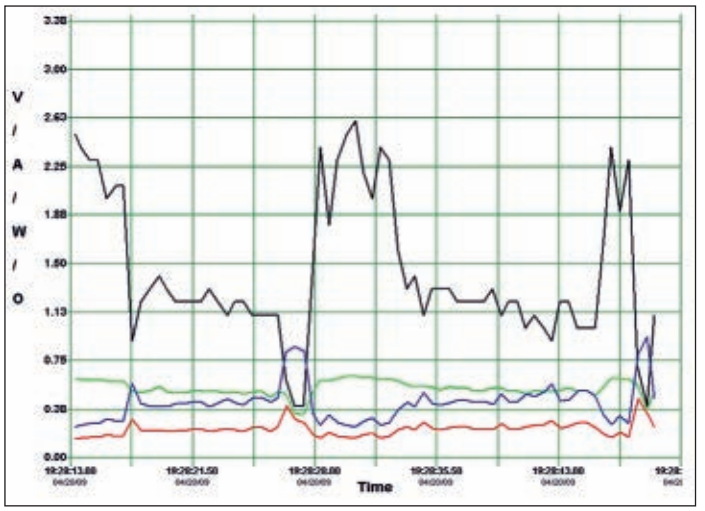


Figure 10. Car Starting and Stopping.

running on a flat surface. For the reverse procedure, I placed the car at the top of the ramp and let it travel down. **Figure 13** shows what happens when the car descends the ramp.

Figure 12. Car Climbing a Ramp.

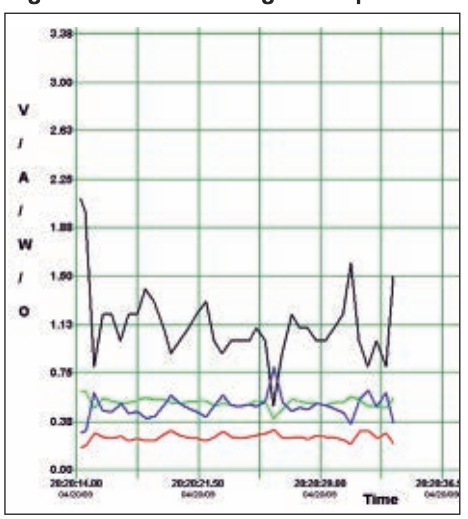
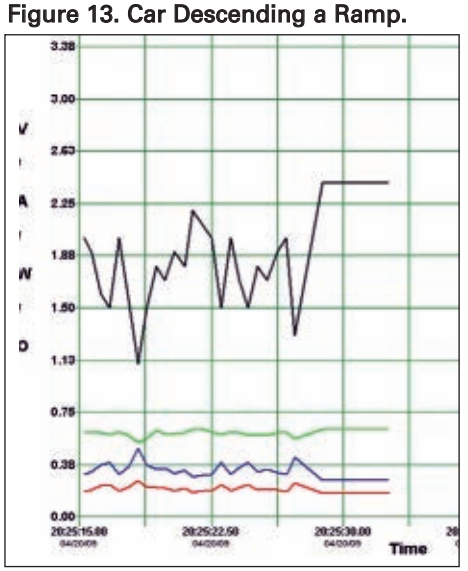


Figure 13. Car Descending a Ramp.



The resistance is higher and the underlying current and power are lower — not by much but it is measurable, nevertheless. I didn't have time to run anymore tests with steeper ramps, but I'm sure that equivalent results will prove that even more power is needed to climb them.

Adapting Telematics to Other Model Cars

While the Hydrocar is a great example of what can be done with remotely monitoring live data, the telematics boards can be adapted to any number of model cars that you or your kids have lying around gathering dust. Just find the wires going between the battery and the motor, and bring them up to the transmitter board's terminals. **Figure 14** and **Figure 15** show how I adapted it to a popular model solar car.

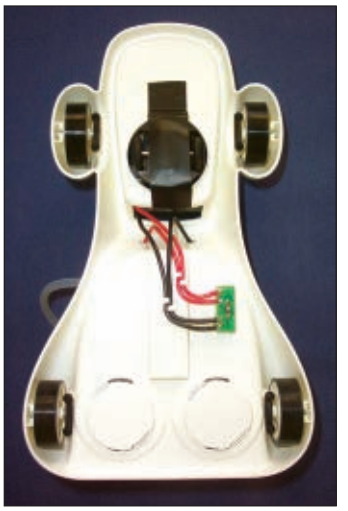


Figure 11. Holding the Wheels in Place with Tape.

Since you won't be using a fuel cell (presumably), the hookup will be slightly different; that is, you'll need to move the solar panel or the car's internal battery wires to the fuel cell terminals. Again, the telematics transmitter and receiver boards are adaptable to many battery and solar powered model cars that will allow you to see exactly what's happening when they're put in motion.

Summing Up

This is the last in our series on fuel cells for the time being, so I hope you enjoyed learning about this technology as it shows definite future promise for many stationary and mobile applications. While fuel cell technology may still be forthcoming in terms of everyday consumer products, telematics is already here and growing in popularity. Its impact will affect not only how we drive but where we drive to and what we purchase along the way. As more and more cars are equipped with wireless Internet communications and GPS, you can expect commercial advertising to appear on your car's map navigation screen as you drive along the highway. Ads for food, fuel, hotels, and motels will pop up on your car's flat panel screen enticing you to pull in and buy what they're selling. A new world of driving is about

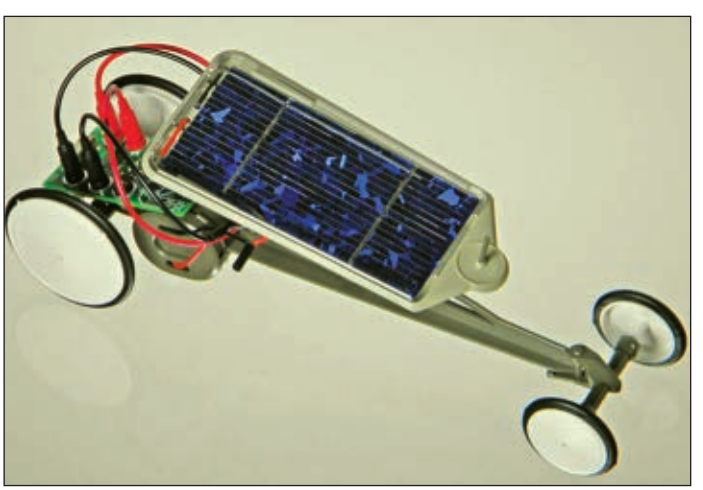
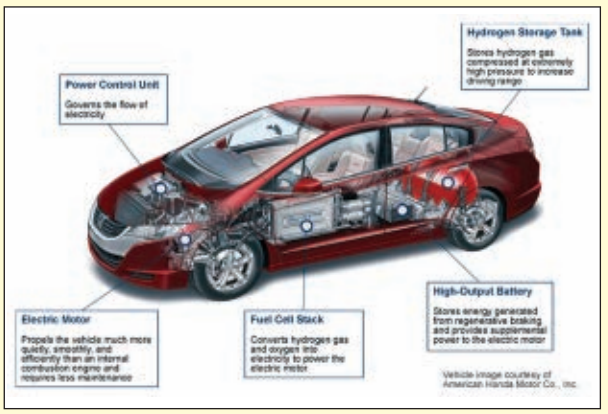


Figure 14. Adapting Other Model Cars to Telematics.

Honda's Solar Power Charging Station for its FCX Clarity Fuel Cell Car

Honda has unveiled a solar-powered hydrogen station for use by drivers at home which can produce enough fuel to power its FCX Clarity fuel cell car for 25 miles of driving each day. Honda's website boasts that its new FCX Clarity fuel cell vehicle has twice the driving energy efficiency of a standard compact hybrid-electric vehicle and three times the efficiency of a compact internal combustion engine vehicle fueled solely by gasoline.



Hydrogen can be used as a fuel for electric cars, thereby doing away with the need for a battery — these so-called fuel cell vehicles can travel longer distances than electric vehicles that need to be re-charged directly from a mains supply.

Honda's solar hydrogen station is the smallest of its kind and could be incorporated into the design of a garage. A spokesperson for the Environmental Transport Association (ETA) said: "At present, there is no refueling infrastructure for hydrogen so personal generators could be part of the answer." The Solar Hydrogen Station is able to export any excess electricity to the national grid.

Author's comment: The sleek design of the solar charging station is impressive, but it appears that integrating it into a typical garage setting will require changing its esthetics to accommodate more standard roof solar panels.

Credit ***http://fuelcell.magasite.net*** *and Honda Motor Corporation.*

to emerge very soon and your next car will [hopefully] be up to the task with electric motors that replace the internal combustion engine that are powered by batteries or fuel cells, or maybe a combination of both.

On a side note, due mainly to my time constraints, future articles in this series will appear bi-monthly. This will give me more time to research the vast amount of alternative energy topics that emerge daily and put them in a form that's adaptable to electronics and programming. I have a few articles in mind already and more that show promise. So, until next time ... conserve energy and "stay green." **NV**

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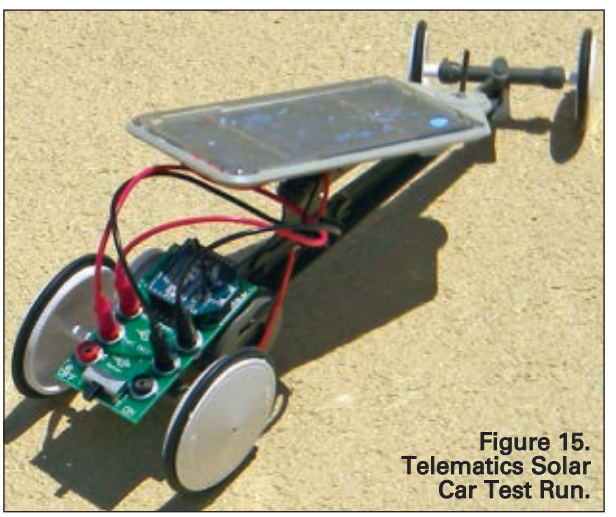

Figure 15. Telematics Solar Car Test Run.

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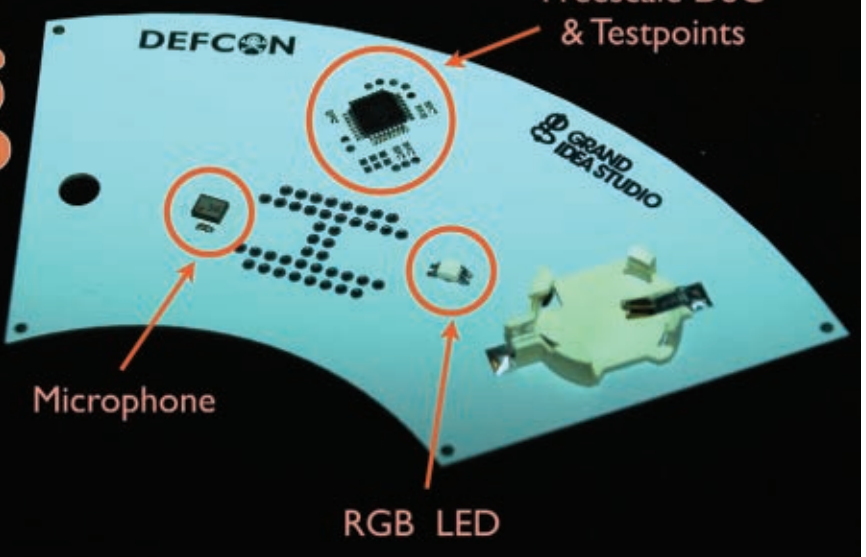
Making The DEFCON 17 Badge

By Joe Grand



(All photos and figures by Joe Grand)

Every summer, thousands of hackers and computer security enthusiasts descend into Las Vegas for DEFCON (**www.defcon.org**) — the largest and oldest continuously running event of its kind. It's a mix of good guys, bad guys, government officials, and everyone in between — all focused on having fun, sharing technical information, seeing old friends, and learning new things. For the fourth year in a row, I've had the honor of designing the conference badge for DEFCON. My goal for the badge is to have an active embedded system that is not only nice to look at, but provides unique and interesting functionality for the attendees. This article covers the engineering behind the DEFCON 17 badge and the problems I encountered along the way.

A Brief History of the DEFCON Badge

The previous years' electronic badges provided their share of challenges and learning experiences:

The DEFCON 14 badge was a round PCB with a complicated cutout of DEFCON's iconic happy face logo and consisted of a six-pin Microchip PIC10F202, two jumbo blue LEDs, and a single CR2032 lithium coin cell. The badge had four different LED modes (on, blinking, alternating, random) and a Microchip ICD2 programming interface for attendees to load their own customized firmware onto the badge.

The DEFCON 15 badge was technically more complex, and I incorporated a Freescale MC9S08QG8, a 95 LED matrix (five columns by 19 rows) for custom scrolling text messages, capacitive touch sensors, and unpopulated areas for accelerometer and 802.15.4 wireless support. (You can read all about it in the Jul '08 issue of *Nuts & Volts*.)

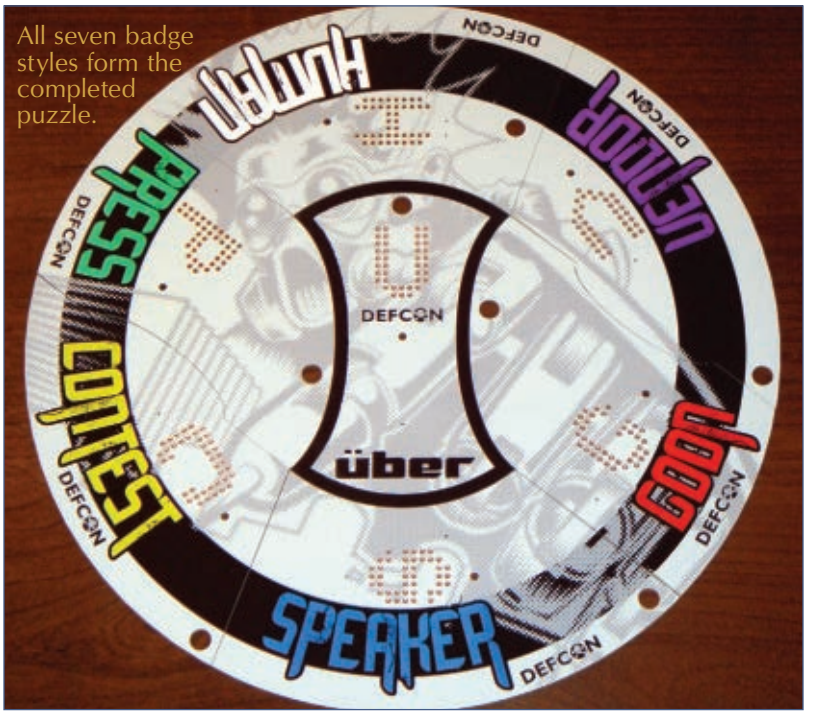
The DEFCON 16 badge boasted a file transfer feature using infrared, allowing an attendee to transfer files stored on a SecureDigital (SD) card to another attendee. If no SD card was present, the badge emulated a TV-B-Gone (**www.tv-b-gone.com**) which transmits all known television remote control power-off codes one after another, allowing you to turn off practically any TV in North America, Asia, or Europe. (You can read all about this one in the Mar '09 *Nuts & Volts*.)

Badge Abstract

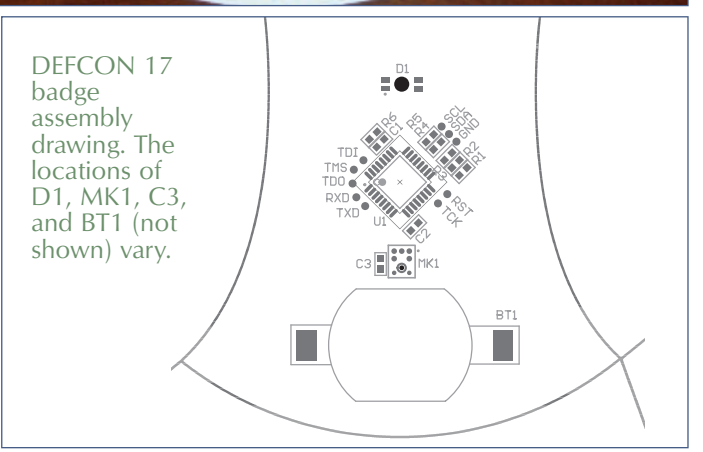
In a nutshell, the DEFCON 17 badge is based around a Freescale MC56F8006 16-bit digital signal controller, a Knowles Acoustics SPM0408LE5H amplified MEMS microphone, and a Kingbright RGB LED. The design is meant to be stark, simple, and elegant. There are very few external components and no buttons or switches for user interface control. The only input is the microphone and the only output is the LED.

The badge operates using a very simple state machine. Its three modes are determined solely by the sound level received by the microphone:

- **RGB Blend a.k.a., Idle**: The LED slowly blends through a pattern of colors. Occurs when the sound level is below a pre-defined threshold.
- **Color Organ a.k.a., Party**: The multicolor LED changes color and brightness, depending on audio input volume and frequency. The LED will "pulse" along to spoken voice or to the beat of music. Occurs when the sound level is above a pre-defined threshold.
- **Sleep**: Occurs when the sound level is below a pre-defined threshold for 15 seconds.



All seven badge styles form the completed puzzle.



DEFCON 17 badge assembly drawing. The locations of D1, MK1, C3, and BT1 (not shown) vary.

Two undocumented modes occur when the audio input meets certain specifications (we'll disclose those later in this article).

Other features include multi-badge communication via a wired interface and a static serial bootloader for in-the-field firmware upgrades. A single CR2032 3V Lithium coin cell battery provides the required power. The printed circuit board (PCB) features complicated mechanical outlines, multiple layers of non-standard silkscreen colors, and a small 0.1" pitch arrangement of pads that serve as a prototype area for badge hacking. All components are mounted on the back of the badge which makes the front side clean and completely available for artistic elements.

Seven unique badge shapes were used to denote the types of DEFCON clientele: Human, Goon, Press, Speaker, Vendor, Contest Organizer, and Uber (awarded to the winners of official DEFCON contests). Each shape serves as a puzzle piece and the puzzle can be completed by placing the seven badges in the correct positions.

Microcontroller

The heart of our badge (U1) is the Freescale MC56F8006 digital signal controller (**www.freescale.com/webapp/sps/site/prod_summary.jsp?code=MC56F800x**) which combines the processing power of a digital signal processor with the functionality and peripherals of a microcontroller. The MC56F8006 is part of the 56800/E family and is extremely powerful. It features — among other things — 16 KB of Flash; 2 KB of RAM; a six-channel PWM module; 18-channel 12-bit analog-to-digital converter; two programmable gain amplifiers; three analog comparators; programmable interval timer; serial communication interface/UART; real time counter; I^2C and SPI ports; and up to 22 general-purpose I/O lines — all crammed into a 32-pin LQFP with a 7 mm x 7 mm footprint. The part supports 1.8V-3.6V operation, and clock speeds up to 32 MHz. The DEFCON badge is configured to run at 8 MHz.

RGB LED

D1 is a Kingbright (**www.kingbrightusa.com**) AAA3528SURKQBDCGKC09 surface-mount RGB LED. This device features three individual diodes (red, green, and blue) in a single four-pin, 3.5 mm x 2.8 mm package. The package comes in a rear-mounting configuration which allowed me to mount the part on the back side of the PCB and drill a small hole through to the front side for light to pass. Luminous intensity is 200 mcd, 80 mcd, and 90 mcd at 20 mA for red, green, and blue, respectively.

The red, green, and blue diodes are connected in a sink configuration to U1's PWM0, PWM1, and PWM2

outputs, respectively. Each diode's brightness is affected by changing the PWM duty cycle of the preferred channel. For each channel, the duty cycle can range from 0xFFFF (LED full off) to 0x0000 (LED full on), but is limited in firmware to a minimum of 0x4FFF to help limit LED current consumption. A single resistor, R6, serves as the current-limiting resistor for all three diodes within the package. By doing so, I could remove the need for two additional resistors (one resistor for each diode), but this means I can only have one color on at a time to achieve consistent brightness control. I used U1's Timer 1 to create an RGB LED multiplexing routine which would enable each individual LED in a cyclical fashion every 1 mS — fast enough to be unnoticeable to the human eye.

Microphone

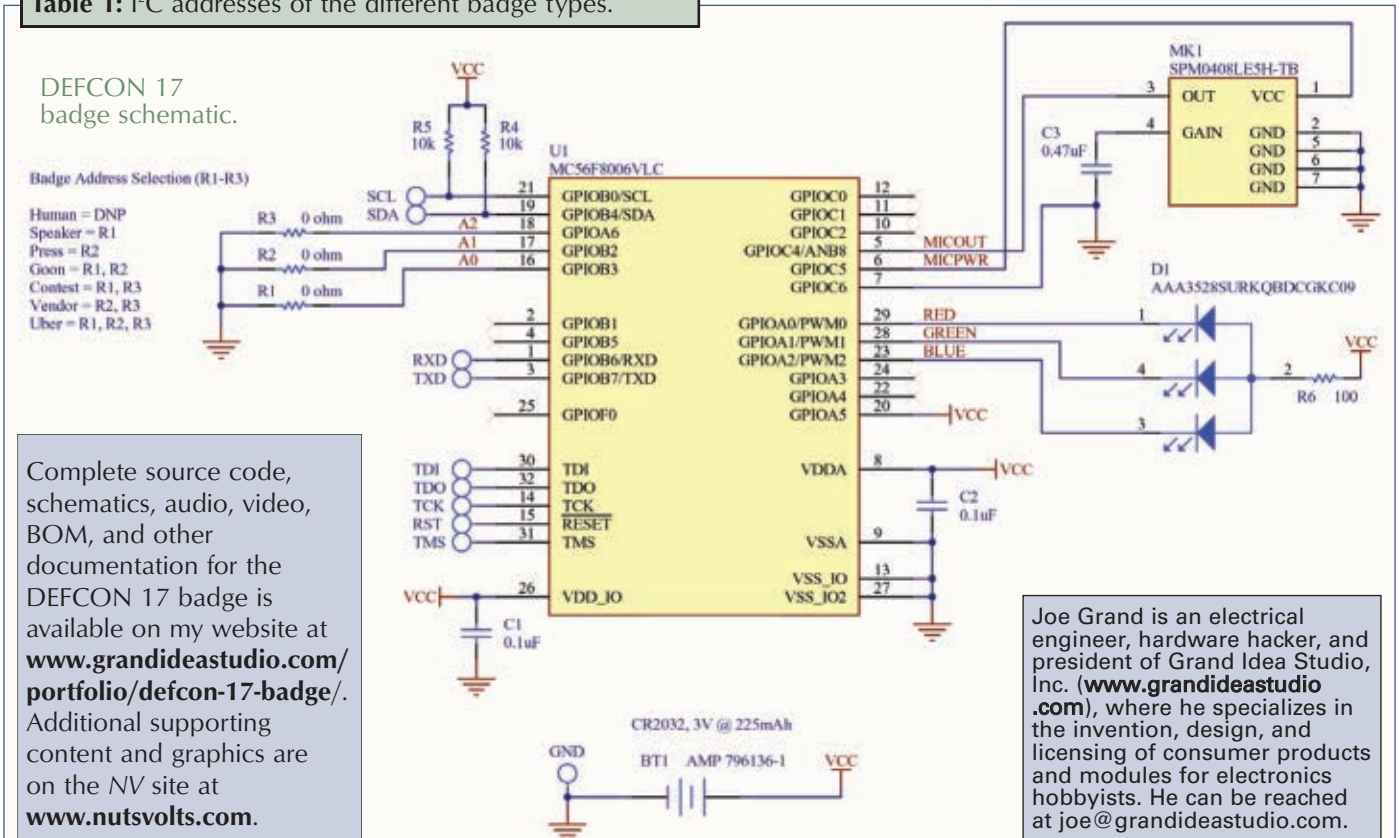
MK1 is a Knowles Acoustics (**www.knowles.com**) SPM0408LE5H SiSonic analog amplified surface-mount MEMS microphone. Over one billion of their MEMS microphones — mainly used in high volume consumer products like mobile phones, laptops, digital cameras, and headsets — have been sold since their launch in 2003. Like D1, the package comes in a rear-mounting configuration, so it's mounted on the back side of the PCB, and a small through hole is aligned with the microphone's sound input port. The device footprint is very small, measuring approximately 4.7 mm long x 3.7 mm wide x 1.25 mm high, and is the only part on the badge that can't be soldered by hand (there are no accessible pins; only solder pads underneath the package).

The microphone features adjustable amplification which is set with an external resistor (optional) and a capacitor. The DEFCON 17 badge sets MK1 for its maximum gain of 20 dB via C3. Internal amplification is especially useful, since I avoid having to externally pre-amplify the microphone signal before passing it to the microcontroller. The MC56F8006 does have two internal programmable gain amplifiers that I possibly could have used with a non-amplifying microphone, but since I was locking in the hardware design much earlier than completing the firmware, I didn't want to commit to that. MK1's OUT pin connects directly to ANB8 of U1 — a single 12-bit A/D channel. Since the microphone requires very little current to function (between 100 uA and 350 uA), I used a general-purpose I/O pin, GPIOC5, connected to the microphone's VCC line to power the microphone directly. This let me completely shut off power to the microphone when it wasn't in use, and then enable the microphone only when the badge was awake.

Badge Type	R1-R3	A2..A0	I²C Address
All	N/A		0 (Broadcast)
Uber	R1, R2, R3	000	1
Goon	R1, R2	001	2
Contest	R1, R3	010	3
Speaker	R1	011	4
Vendor	R2, R3	100	5
Press	R2	101	6
Unused	N/A	110	7
Human	DNP	111	8

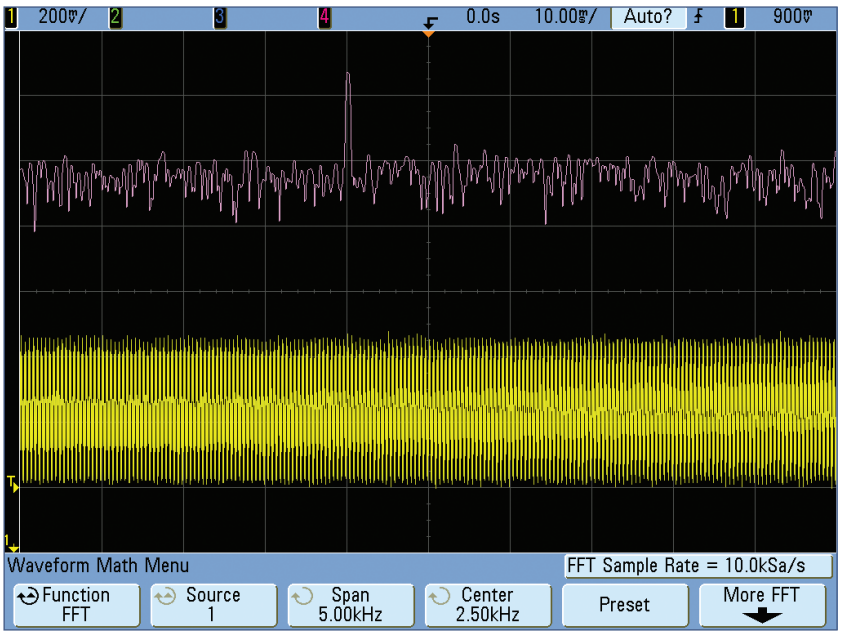
Table 1: I²C addresses of the different badge types.

DEFCON 17 badge schematic.



Complete source code, schematics, audio, video, BOM, and other documentation for the DEFCON 17 badge is available on my website at **www.grandideastudio.com/portfolio/defcon-17-badge/**. Additional supporting content and graphics are on the *NV* site at **www.nutsvolts.com**.

Joe Grand is an electrical engineer, hardware hacker, and president of Grand Idea Studio, Inc. (**www.grandideastudio.com**), where he specializes in the invention, design, and licensing of consumer products and modules for electronics hobbyists. He can be reached at joe@grandideastudio.com.



A sine wave (yellow) processed through an FFT function (purple). Each vertical division corresponds to 500 Hz and the screen spans from 0 Hz to 5 kHz. A very distinct peak appears at the fourth division with no significant peaks anywhere else — meaning the input was a pure 2 kHz signal.

Development Environment

Source code was developed in C using the freely available CodeWarrior for 56800/E Digital Signal Controllers Special Edition (**www.freescale.com/webapp/sps/site/prod_summary.jsp?code=CW-56800E-DSC**).

Fast Fourier Transform (FFT)

A fast Fourier transform is a mathematical function used to split sounds into their discrete frequency elements and is *the* core element of the DEFCON 17 badge. The FFT is a complex and processor-intensive function suited for a DSP or DSC, fitting in perfectly with our microcontroller selection. Detailed information on FFTs can be found at **http://en.wikipedia.org/wiki/Fast_Fourier_transform** and **www.edn.com/article/CA6643362.html**.

On the badge, the FFT function takes in the audio signal from the microphone via a 12-bit analog-to-digital conversion at an 8 kHz sample rate and separates it into four discrete bins. Each bin corresponds to a particular frequency range. The power of three of the four bins are calculated and those values are used to directly set the color and brightness of the red, green, and blue elements of the LED:

```
PWMRed_SetRatio16(~(unsigned int)FFTVal[0]);
   // Bin 1
PWMGreen_SetRatio16(~(unsigned int)FFTVal[1]);
   // Bin 2
PWMBlue_SetRatio16(~(unsigned int)FFTVal[2]);
   // Bin 3
```

There are two other modes triggered when the audio input meets certain specifications for a given amount of time:

1) When the badge detects a specific frequency of 2 kHz being played for a few seconds, it uses the RGB LED to blink a secret URL in Morse code.
2) When the audio level received by the microphone remains above the pre-defined threshold of Party mode for 15 minutes, the RGB LED will blink an "SOS" mayday call three times in Morse code. If this mode gets triggered, the attendee is having too much fun and needs to take a break!

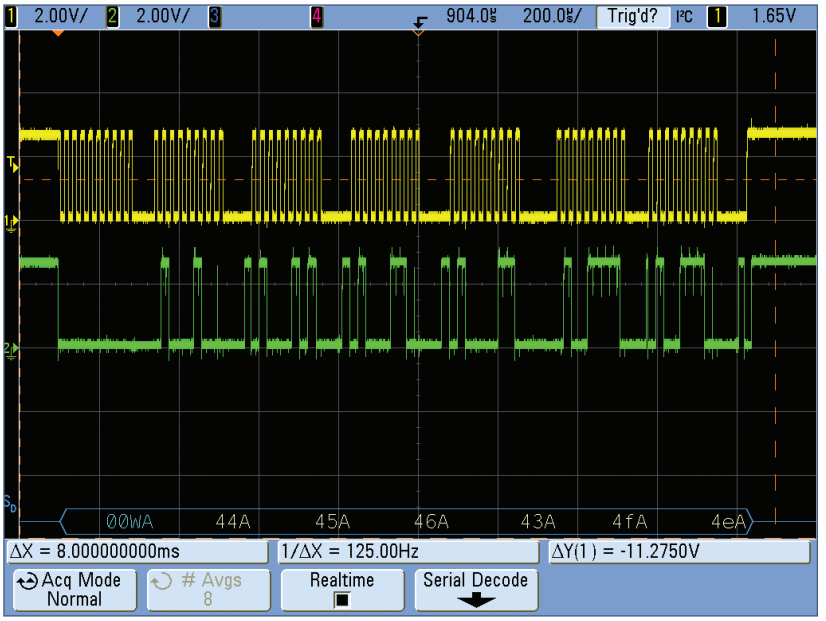
Badge-to-Badge Communication

Not only do the badges connect together mechanically as a puzzle, but up to seven of them can be connected electrically and communicate with each other via I²C. Using only two pins (SCL, Serial Clock and SDA, Serial Data) and ground, the Human badge serves as the master and communicates with all the other badge types which are slaves on the bus. This feature was designed purely with social interaction and badge hacking in mind. The expectation was that conference attendees with different badge types would join forces and connect them together to see what would happen. Only one team actually did that. When badges are connected together, the default functionality is for the master badge to control the RGB LED state of all the slave badges and cycle through a variety of different colors. Having run into problems with communication reliability in attempting to do a "hot plug" detection of badges connecting to the bus, my final implementation had only the master checking for slave badges on power-up. This meant that all slave badges had to be turned on first before applying power to the master. Each badge on the bus is individually addressable and its address (A2-A0) is set by the presence or absence of three zero ohm resistors (R1-R3) on the circuit board according to the **schematic** and **Table 1**.

Notice in the **graphic** (on the following page) an oscilloscope capture of badge-to-badge data being transmitted over the I²C bus. The packet length is seven bytes. The first byte is the destination address (0x00 is the broadcast address that is accepted by any badges on the bus). The remaining six bytes form three 16-bit words, each corresponding to the PWM duty cycle of the red, green, and blue diodes in the RGB LED. When the slave badge receives the packet, it will parse the data, set the PWM registers accordingly, and then wait for another packet to be received.

Bootloader

In order to provide a mechanism for attendees to easily load new firmware into U1's Flash memory to aid in badge hacking and customization, I implemented a static bootloader based heavily on Freescale's AN3814



A packet of badge-to-badge data on the I2C bus.

application note. The bootloader communicates via U1's RXD and TXD serial pins at 19.2 kbps and is enabled for the first 10 seconds when the badge is initially powered on. The RGB LED will alternate colors between red, green, and blue, indicating that it is in the bootloader mode awaiting data. During this mode, you are able to load firmware onto the badge by simply uploading the text-formatted S-Record file of your program (generated by CodeWarrior) using a simple terminal program, such as HyperTerminal or ZTerm. If the badge doesn't receive the proper S-Record file within those initial 10 seconds, it will jump to regular program operation.

For aesthetic reasons, no discrete connector or unpopulated footprint is provided, so attendees had to solder a serial interface (e.g., a level shifter to convert the 3V TTL-level serial of the badge to RS-232 or a hacked USB-to-serial adapter to accept TTL-level signals) directly to test points on the badge. I felt that this was a reasonable level of entry for those who wanted to take advantage of this functionality. Here's an example of the text output during bootloader usage:

```
Serial bootloader started.
Waiting for application S-Record.
PROGRAM&DATA**********************************
*****************
Download complete.
Starting user application.
Welcome to the DEFCON 17 Badge.
```

If the firmware gets corrupted through a faulty programming operation, test points for the MC56F8006's JTAG interface (TDI, TMS, TDO, TCK, and RST) are available on the circuit board; these can be used for complete firmware reprogramming (including the bootloader) and full debugging using CodeWarrior and the USB TAP hardware (**www.freescale.com/webapp/sps/site/prod_summary.jsp?code=USBTAP**). Most people who used the JTAG interface soldered a 2 x 7 male header (which is compatible with the USB TAP) onto the prototyping "area" of the badge and connected wires to the individual test points.

Mode	Current @ VCC = 3V
RGB Blend a.k.a., Idle	4.8 mA - 8 mA (6.4 mA avg.)
Color Organ a.k.a., Party	4.3 mA - 7.2 mA (5.75 mA avg.)
Sleep	1.2 mA

Table 2: Current consumption measurements for the three badge modes.

Battery Life

After using a beefy, heavy CR123A lithium battery for DEFCON 16, I wanted to go back to the slim, low-cost CR2032 lithium coin cell I used for the other years. The CR2032 has a very nice current capacity for its size (20 mm in diameter) of approximately 225 mAh. Even though the cell can handle 3 mA continuous discharge and upwards of 10 mA pulse current, the lithium battery chemistry works best for applications requiring very low continuous discharge current (e.g., tenths of an mA) over months or years of use.

When designing any portable device, one challenge is meeting your desired battery life specifications. For the badge, my intent was to have a single battery last the entire weekend conference, but I was not as stuck on this requirement as I had been in previous years. As long as I could get reasonable battery life, I would be happy — especially considering that the badge would be performing processor-intensive functions like FFTs much of the time. The decision to use a CR2032 versus something with a little more capacity (hence, larger) was a conscious engineering trade-off. In this case, looks mattered more than functionality.

Table 2 shows the current consumption for the badge's three modes. It was slightly higher than the recommended current discharge, meaning total battery life would be affected. To reduce power consumption and prolong battery life while the badge wasn't being used, I implemented an automatic sleep mode for U1. This mode would be entered when the sound level detected by the microphone was lower than a pre-defined threshold (set in firmware) for 15 seconds.

Once the unit was asleep, U1 would wake up every one second, check for sound, and go back to sleep if there was still nothing above the threshold. If the sound level detected *was* above the threshold, U1 would switch into either the RGB Blend or Color Organ mode, depending on how loud the sound was. A Sleep mode current of 1.2 mA is still quite high, and I feel that I could have spent more time to reduce it further.

With the current consumption measurements in hand, I then calculated some estimates of battery life based on "typical" DEFCON attendee use of the badge. Although one would argue that most DEFCON attendees barely sleep at all, assume the badge spends eight hours in each mode per day:

8 hours @ RGB Blend,
6.4 mA = 51.2 mA
8 hours @ Color Organ,
5.75 mA = 46 mA
8 hours @ Sleep,
1.2 mA = 9.6 mA
Total current consumption
per day = 106.8 mA

CR2032 typical current capacity
(down to 2V cell voltage) = 225 mAh
Estimated battery life = 225 mAh /
106.8 mA = 2.1 days

Prototype hardware using the MC56F8006DEMO reference board.

Real-world use seemed very close to this estimation. Those who registered earlier in the weekend would notice the blue diode on their RGB LED getting dimmer and, as the battery voltage fell well below the diode's forward voltage, failing to illuminate at all. Green would go next, followed by red. The microcontroller and microphone could operate down to 1.8V and 1.5V, respectively, so they'd remain alive and well (but somewhat useless without the badge's visual indicator).

Development Timeline

After the too-close-for-comfort, last minute arrival of DEFCON 16 badges to the conference last year, I vowed to start this project much earlier and to add enough cushion into the engineering schedule to make sure the badges were completed well ahead of time. Also, my son, Benjamin, had recently been born, adding unfamiliar, new parent challenges — like extreme sleep deprivation, non-maskable-interrupting diaper changes, and lack of quiet hours dedicated to work. The project officially got underway in December 2008. The initial design and parts selection were completed relatively quickly with few issues. Because of the parts sourcing and supply chain problems I encountered last year, I took extra steps to ensure that the components I selected for the design were immediately available or had a short leadtime that I could work directly with the manufacturer to manage.

By January 2009, I already had prototype hardware completed using a Fresscale MC56F8006DEMO board with the additional LED and microphone components soldered onto it. At this point, even though the final firmware wasn't close to being done, I had written enough low-level code to prove out the basic constructs and the prototype hardware verified that my physical interconnects were correct. Since the hardware design was simple and straightforward, I decided to jump directly to the true-to-form circuit board design without any interim layouts. The PCB design was completed in February.

In March, I ordered all the production quantities of components and focused on finishing the firmware. The firmware design was a bit tricky, as I thought I had functionality working great. But, when I demonstrated the badge to the DEFCON organizers in person, they discovered a few critical bugs. Much to my chagrin, I had to rewrite large chunks of code to squash them. By the end of April, the firmware was finally completed and programmed into the microcontrollers.

By May, I started shipping all the components to e-Teknet — our manufacturer in China. We were so far ahead of previous years' schedules that the organizers and I thought "There's no way anything can go wrong. We have so much time." The month of June was spent waiting for parts to arrive in China and pass through Customs.

Just when I thought we were home free, I noticed that a single box I shipped on May 21 had been sitting in Chinese Customs for two weeks with no progress. As Murphy's Law would dictate, this box contained all of the programmed microcontrollers and custom-built LEDs — both integral to the design. We still had a few weeks to take corrective action and, while on a trip to the Middle East with little Internet access and poor cell phone reception, I placed orders for new components just in case the original box didn't get released in time. An added wrinkle was that — due to manufacturing leadtimes — I could only order partial quantities of components which meant fewer people would get badges if we had to use this option. Not good.

After daily communication with UPS and e-Teknet, attempts to contact Chinese Customs, and nervous, sleepless nights, the package in question was finally released without explanation and delivered to the factory on July 22, only nine days before the start of DEFCON (last year's packages that were stuck in Customs were delivered to the factory four days before the start of DEFCON). e-Teknet scrambled into action and, each day, they sent a few thousand pieces directly to the conference venue as they came off the assembly line.

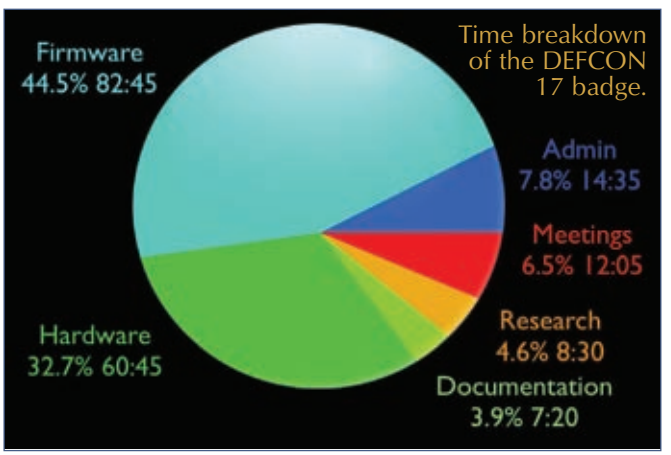
Despite our early start and extra precautions, the final batch of badges arrived only one day earlier than last year (on Saturday instead of Sunday). Long lines formed in front of the DEFCON registration area for people to swap out their temporary plastic badge for the real deal. Attendees missed talks and opportunities to hang out with friends in order to stand in line for hours. Once again, the badge delay was a topic of conversation throughout the weekend. I certainly don't want this becoming the norm. Having run into problems two years in a row and knowing our luck will eventually run out, we are considering having our PCBs fabricated by e-Teknet in China, but then assemble the badges in the United States. The approx. 300% increase in

cost may well be less than the expedited shipping fees and Customs charges we've had to pay in the past.

By the Numbers

All told, the DEFCON 17 badge project took 186 hours. The majority of time was spent on firmware design which is not surprising as I had to familiarize myself with the features of Freescale's MC56F8006 and learn about FFTs and how to implement them. The **pie chart** shows the time dedicated to each aspect of the project.

A total of 6,694 badges were manufactured with seven unique badge shapes:

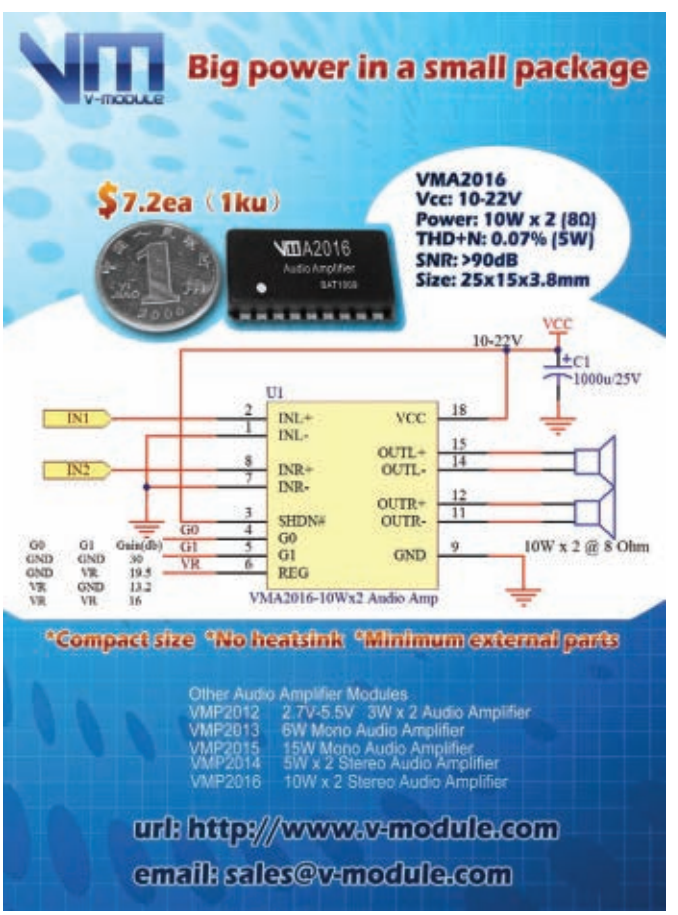


- Human (5,844 pieces)
- Goon (200)
- Press (200)
- Speaker (200)
- Vendor (100)
- Contest Organizer (100)
- Uber/VIP (50)

The cost per badge was $7.05, not including taxes or shipping. The highest priced line item was the PCB fabrication, manufacturing, assembly, and testing at $2.70 per piece (very reasonable considering the complicated routing and additional silkscreen steps). The microprocessor and microphone cost $1.50 and $1.00, respectively. Both Freescale and Knowles Acoustics gave us great quantity discounts even though our quantities were relatively small compared to their typical accounts.

Until Next Year ...

At the conference's closing ceremonies, a DEFCON organizer spurred on thousands in the crowd to chant "BADGES BY CHRISTMAS, PLEASE!" with the hope that next year's badges would be completed eight months in advance. Well, that's easier said than done and since no one knows for sure what sort of problems I'll encounter with the DEFCON 18 badge design, we'll all just have to wait and see if I can pull it off! **NV**



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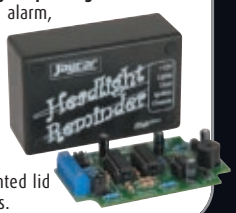

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- PCB: 112 x 87mm

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- Double-sided plated PCB
- Programmed PIC
- Electronic components
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Recommended with this kit:
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KC-5434 $10.00 plus postage & packing

An extremely useful and versatile kit that enables you to use a tiny trigger current as low as 400µA at 12V to switch up to 30A at 50VDC. The kit includes PCB with overlay and all electronic components with clear English instructions.

KIT OF THE MONTH

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KC-5489 $52.25 plus postage & packing

Host your own website on a common SD/MMC card with this compact Webserver In a Box (WIB). It connects to the Internet via your modem/router and features inbuilt HTTP server, FTP server, SMT email client, dynamic DNS client, RS232 interface along with four digital outputs and four analog inputs. Requires a SD memory card, some SMD soldering and a 6-9VDC power adaptor. Kit includes PCB, case and electronic components.

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#24 SMILEY'S WORKSHOP

C PROGRAMMING - HARDWARE - PROJECTS

AVR Memory Part 2: EEPROM

Follow along with this series! Joe's book & kits are available at www.nutsvolts.com

by Joe Pardue

Recap

Last month, we introduced computer memory and learned a little about how the C programming language uses pointers for addresses to data variables. We also learned to use Pelles C to test C programming concepts on a PC. This month, we will get back to looking at examples for the AVR memory as applied to reading the EEPROM.

Pointer Review

Yes, we belabored this last month but I've never felt comfortable explaining pointers because I still tend to mess them up. (I remember how many false starts I had trying to learn them.) On the surface, they are simple: A pointer is a memory location containing the address of another memory location. In C, a pointer is a data type for a variable intended to hold the address of another variable. You tell C that a data type is a pointer by marking it with an asterisk '*'. So, when you define char *myCharPointer, you are telling the C compiler that myCharPointer is the address of a character. Then, if you want to set this variable to the address of a char, you use the '&' operator to extract it. So, if you define char myChar = 'a', you can get the address of myChar by stating myCharPointer = &myChar. This may sound simple, but implementation can be the killer.

Cliff Lawson — the number one poster on AVRFreaks — manages large software projects with 50+ programmers and he says that 50% of the bugs come from pointers. And his guys know what they are doing. So, expect to have to approach learning about pointers many times and from many directions. The best thing I can suggest to help you learn to safely use pointers is to write small pieces of code and thoroughly test them before including them in larger pieces of code.

When you get experienced enough that pointers seem second nature, that's when you will start to get into real trouble and you'll get bugs that drive you, well ... buggy. That's part of the price of admission to C programming of microcontrollers. (Hey, what a nice title for a book — and coincidentally, a book that you can get from *Nuts & Volts*, along with an excellent hardware projects kit to give yourself a leg up on this C stuff.)

More on Computer Memory

An ideal computer as imagined by John von Neumann would have a single memory that holds the program and data. In the real world, however, memory speed and cost play a role, and few real computers are entirely von Neumann in their architecture. Computers that use different kinds of storage for programs and data are referred to as having a Harvard Architecture, and most contemporary microcontrollers use modifications of this concept.

When a computer is running, it must **read** the ***program memory*** as rapidly as possible. Based on the instructions contained in program memory, it **reads** and **writes** ***data memory***. The main difference in the program and data memory areas is that the computer only needs to read program memory, but it must both read and write to data memory. It turns out that from a hardware perspective, it is much cheaper to make memory that is mostly read from, than memory that is both read and written to. So, to fit these different needs and economies, two types of memory were developed. For data, we use RAM (Random Access Memory) that can be easily written to and read from. RAM can be **volatile** meaning that it doesn't matter if it loses its data when the power is off. However, for the stored program that is mostly read we use ROM (Read Only Memory). ROM must be **non-volatile** so that it can retain the program when the power is off. ROM is much cheaper to manufacture than RAM. You often see computers with plentiful, cheap ROM, but with much smaller amounts of the more expensive RAM.

The terminology isn't 100% clear, of course, because if ROM is read only, how do we store (write) the program on it in the first place? The answer is that it's really a 'read mostly' design that can be written to — usually very slowly and only with special programming equipment. But, as we will see in a minute, one of the innovations of the AVR was that it uses a special type of ROM (Flash EEPROM) for the program memory that allows it to be programmed by ISP (In System Programming).

SRAM

SRAM (Static Random Access Memory) is fast but

expensive relative to Flash. As you can see in **Table 1**, AVRs have much more Flash than SRAM. Reading and writing SRAM with C is a piece of cake since all you need to do is assign a variable; C takes care of assigning SRAM memory locations for the variables. Since so much of the C programming language was written for use with RAM, we don't need to learn anything special to use it. The same can't be said for ROM, however.

AVR	SRAM Bytes	EEPROM Bytes	Flash Bytes	Pins	Cost*
ATmega48	512	256	4096	28	2.69
ATmega168	1024	512	16384	28	4.11
ATmega328	1024	512	32768	28	4.30
ATmega644P	4096	2048	65536	40	7.76

*Cost from Digi-Key 2010 Catalog — DIP Package

Table 1. Typical Memory for AVRs.

AVR ROM

EEPROM Versus Flash EEPROM

In Smiley's Workshop 22 (*Nuts & Volts* May '10), we mentioned the difference between EEPROM and Flash EEPROM in the context of bootloaders and Baron Munchhausen (who saved himself after a shipwreck by pulling himself out of the ocean by his own bootstraps). [Yes, it *was* relevant]. These two memory types differ mainly in that for EEPROM, each byte can be read or written individually which requires a lot more circuitry than for Flash, where data is written in large blocks. Less circuitry means lower cost, so Flash is much cheaper. It also means the inconvenience of not being able to deal with data one byte at a time. Most AVRs include both types of memory — reserving Flash for the infrequently written program memory and EEPROM for more frequent writes of small amounts of data that need to be remembered between power cycles.

A further difference is that AVR Flash is rated for 10,000 write cycles (a lot, but not if the data is changed at computer rates), where the EEPROM is rated at 100,000 write cycles. [You can read both all you want with no wear-out problems.] To help get our heads around the meaning of the write cycles, think about updating some data once per hour. You could safely do this for just over 416 days with Flash memory, and 4,166 days (just under 11-½ years) with EEPROM. You can see that doing updates every minute would quickly exhaust both memory types (166.6 hours for Flash and 1,666 hours or 69 days for EEPROM). So, we reserve our frequent writes for SRAM, our semi-infrequent writes to EEPROM, and our rare writes for Flash.

The write ratings are low estimates. You can probably get by with a lot more writes, but Atmel only guarantees the low number in the datasheet. You can also use special programming techniques to extend the use of EEPROM that are beyond the scope of this article, but discussed in the AVR101 application note shown in **Listing 1**.

EEPROM

Let's say we designed a solar powered GPS guided robot that shuts down at night. If we store our GPS waypoints in EEPROM, then the next morning when our robot restarts it can know where it is and how to get back home. [If it turns out that in the morning it is a mile east of where it went to sleep, then it can have the robotic equivalent of a panic attack.]

For most ATmega AVRs, EEPROM memory is not formally available as part of the AVR addressable memory space. Instead, it is accessed as an internal peripheral device. This requires using special EEPROM registers and read/write instructions. Also, EEPROM access is much slower than the AVR SRAM access so timing has to be considered when using the EEPROM. Since we are using C, we don't have to directly mess with the low-level register stuff because we can use the avrlibc library EEPROM functions included as part of the WinAVR toolchain. All you have to do is use the header file EEPROM.h in an AVRStudio program and the underlying tools will link to the functions you need.

You can see the docs about these tools at **www.nongnu.org/avr-libc/user-manual/group__avr__eeprom.html**. Be warned, however, before looking at the web page. This stuff uses the typical proliferation of cryptic (IMHO) data type identifiers from the GCC compiler that tend to befuddle most folks who don't use this compiler on a daily basis. Just don't let the prickly stuff scare you. The test software here is much more warm and fuzzy, or at least less prone to give you a rash.

Watch for Brown Outs

One thing you need to know about EEPROM is that if the voltage gets hinky and falls below a certain value while you are writing to EEPROM, you stand a good chance of corrupting your data. We will set the brown-out fuse on the AVR to help prevent this kind of issue. This problem can get you in trouble with things like the hypothetical solar powered robot which has to detect that the power is failing while it still has enough juice left to record the waypoints.

Using the avrlibc EEPROM Library

The EEMEM Data Type

The EEMEM attribute tells the compiler to assign a

Listing 1: Atmel AVR EEPROM Application Notes.

AVR100: Accessing the EEPROM on tinyAVR and megaAVR Devices
AVR101: High Endurance EEPROM Storage
AVR102: Block Copy Routines on tinyAVR and megaAVR Devices
AVR103: Using the EEPROM Programming Modes on tinyAVR and megaAVR Devices
AVR104: Buffered Interrupt Controlled EEPROM Writes on tinyAVR and megaAVR Devices

variable to EEPROM rather than SRAM. Unfortunately, this attribute can lead to confusion later since there is nothing to stop you from forgetting that you meant to use this variable with the EEPROM. So, you might do something like:

```
uint8_t EEMEM myChar;

// BAD USE OF EEMEM
void myFunc()
{
       uint8_t c;
       c = myChar;
}
```

If you do this, then the compiler thinks myChar is in SRAM and loads the data from the address indicated by myChar — which isn't what you intended.

```
// CORRECT USE OF EEMEM
void myFunc()
{
       uint8_t c;
       c = eeprom_read_byte(&myChar);
}
```

Fine. Now you know how to do it and if you mess up, then it's all your fault for forgetting that six months ago you meant for myChar to be in the EEPROM. Harsh? Yeah, and unrealistic. So, let's apply an arbitrary programming practice to using EEMEM: We promise to always name our variables that we meant to have in EEPROM with the prefix EE_ so instead of myChar, we would use EE_myChar like below:

```
// this is in a header we wrote six months ago
// and have now forgotten about:
uint8_t EEMEM EE_myChar;

// correct and saner use of EEMEM
void myFunc()
{
uint8_t c;
c = eeprom_read_byte(&EE_myChar);
}
```

EEPROM Functions

Read one byte from the EEPROM:
uint8_t eeprom_read_byte (uint8_t *addr)
Returns the byte located at addr.

Write one byte to the EEPROM:
void eeprom_write_byte (uint8_t *addr, uint8_t value)
Writes the value to addr.

Read one word from the EEPROM:
uint16_t eeprom_read_word (uint16_t *addr)
Reads the word (AVR word is 16-bit so data type is uint16_t) at the addr.

Write one word to the EEPROM:
void eeprom_write_word (uint16_t *addr, uint16_t value)
Writes the word at addr.

Read 'n' sequential bytes from the EEPROM:
void eeprom_read_block (void *array,void *array, uint16_t n)
Read 'n' bytes from the EEPROM beginning at the given address and load them into the given array.

Write 'n' sequential bytes to the EEPROM:
void eeprom_write_block (void *array, void *addr, uint16_t n)
Write 'n' bytes from the given array into the EEPROM beginning at the given address.

EEPROM _Test Software

One Code Module, Four Devices

The EEPROM_Test software allows us to test each of the avrlibc EEPROM functions. It is written so that you can use it with four different development environments. Changing one line of code causes it to compile for one of the four. You can use it with AVRStudio and an AVR Butterfly, *or* the BeAVR (ATmega644 we discussed in WS22), *or* an Arduino board. Plus, you can use it with the Arduino board in the Arduino IDE, all by changing one line of code! How cool is that?

Well, as usual, there is a price. This works because the code is cluttered with '#if defined' statements that cause the compiler to only look at certain sections of the code. As the user, you get to look at it all whether you need to or not. For instance, if you are using an Arduino with AVRStudio, you couldn't care less about the Butterfly oscillator calibration; the compiler ignores that section – but the code is there for you to see, anyway. It doesn't get compiled, so it doesn't inflate the Arduino code, but it does add text you have to look past. It's a trade-off that you'll need to get used to if you advance in C programming.

You get to tell the compiler to generate code for one of the following:

```
Arduino // Arduino ATmega328 board with Arduino
IDE - 57600 baud
ATmega328 // Arduino board with AVRStudio/WinAVR
- 57600 baud
ATmega644 // BeAVR board - 16 MHz clock - 57600
baud
Butterfly // The good old Butterfly - ATmega169
- 19200 baud
```

You tell the compiler which one you want to use by removing the comment directive '\\' that is in front of the device that you will be using. Make sure the other devices have that '\\' in front of them or there is no telling what you'll get. This is how you would select the Butterfly:

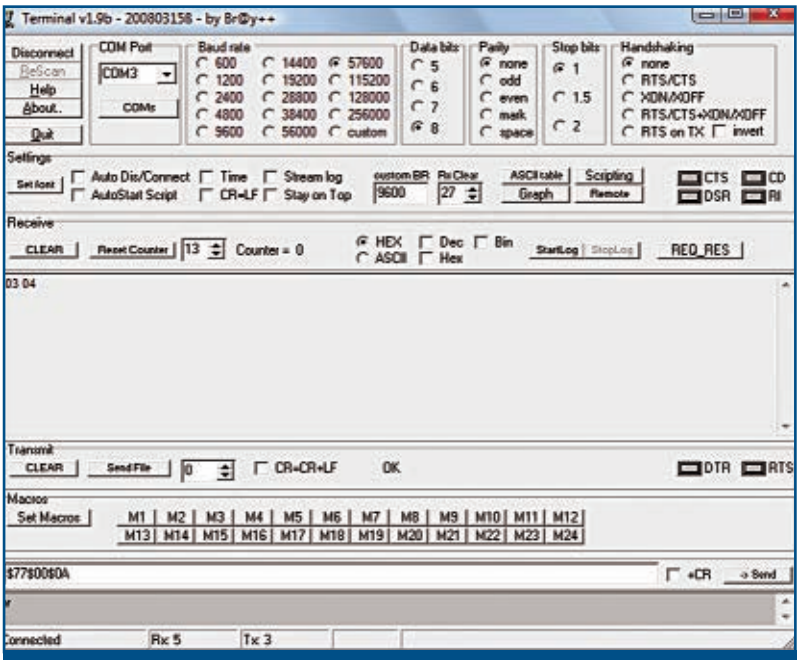
```
//#define Arduino
//#define ATmega328
//#define ATmega644
#define Butterfly
```

Finally, note that if you select 'Arduino,' you must use the Arduino IDE for compiling. If you select 'ATmega328,' you can use the Arduino hardware but must compile using AVRStudio/WinAVR. Also, when using AVRStudio make sure that you select the correct AVR device in the AVR Studio Project/Configuration Options window. If you get a

string of errors complaining about undefined registers, you probably didn't set this to the correct device.

Br@y++ Terminal

We will use Bray's Terminal (a.k,a., Br@y++ Terminal) because my Developer Terminal developed a hiccup in Vista and I don't know if I'll get it fixed by the time this article goes to press. It still works, but it double prints each received byte. I won't subject you to a rant about how annoyed I get when every new Microsoft Windows update breaks my stuff. Anyway, Brays works with Vista and is free, so let's use it. You can get it at **http://sites.google.com/site/braypp/terminal**. This is a great terminal program and the only reason I've rolled my own is that I wanted some features it lacks, but it will do just fine for this demonstration.



■ FIGURE 1. Br@y++ Terminal.

One thing that confuses some folks is that the send textbox is the white single line area near the bottom in **Figure 1** (with the text $77$00$0A in it). You write stuff there and then click the 'Send' button to send text. Many folks mistakenly try to send from the Receive window where you see 03 04 in **Figure 1**. You can send characters using their hexadecimal in Brays by marking them with a '$' rather than '0x' like we are used to. Bray's help file is very brief, but if you pay attention, it's all you really need.

In order to demonstrate how to use the EEPROM_Test code, I've written EEPROM_Test_Send.doc that contains more details about how to use Brays for testing the EEPROM code. [This file is in the Workshop24.zip at **www.nutsvolts.com**.]

The Source Code

Well we are running out of space and haven't even gotten to the source code yet. You can also find it in the Workshop24.zip file.

The materials we discussed this month can be used with either the AVR Butterfly or the Arduino. Both devices are available from *Nuts & Volts* as part of the Book/Projects-Kit combos; either of which can give you a lot of help learning about microcontrollers. If you have any questions, please start a thread on **www.avrfreaks.net** with 'Smiley's Workshop' in the title and I'll probably see it. Next month, we will build on what we've done so far, and tackle the AVR program memory space. I promise that everything

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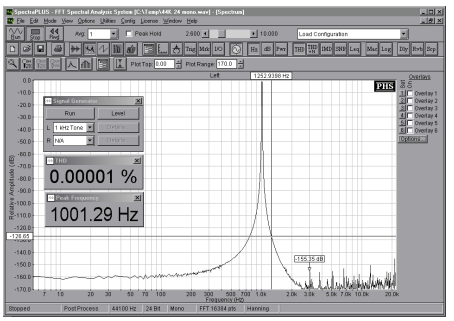

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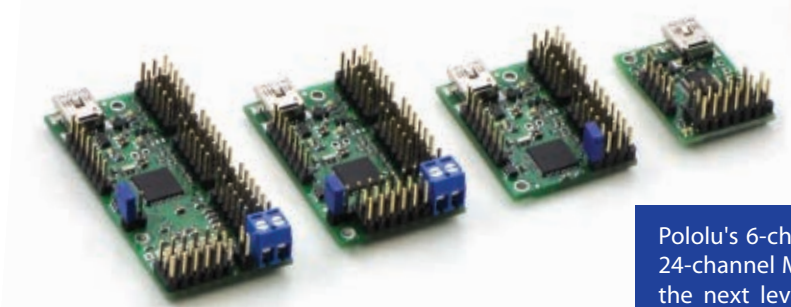

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■ BY FRED EADY

BRINGING A USB-TO-UART PROTOCOL CONVERTER TO LIFE

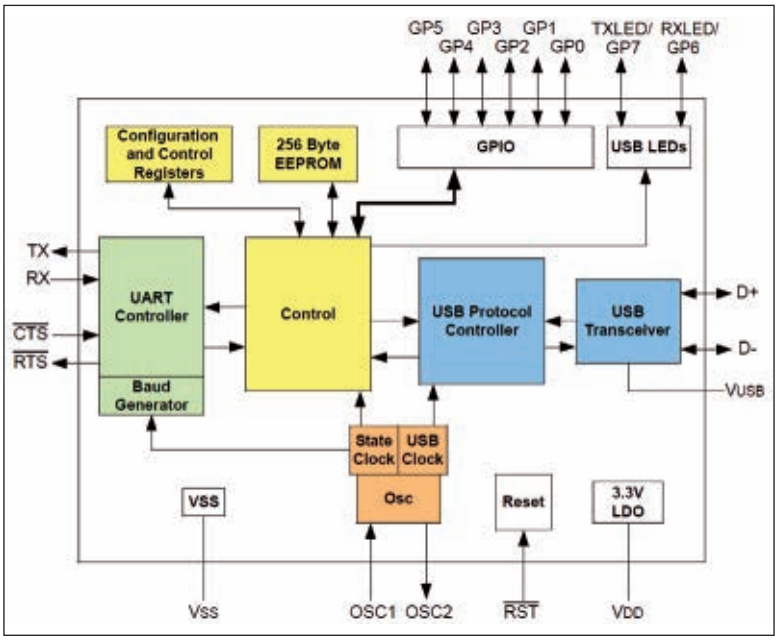
Did you know that Microchip offers a USB 2.0 to UART protocol converter? It's called the MCP2200. The MCP2200 is not totally limited to performing USB-to-serial conversion duty. Outfitted in 7.5 mm (.300 inches) SOIC packaging, the MCP2200 resembles a PIC in form and function by providing an octet of GPIO (General-Purpose Input/Output) pins and EEPROM. In this edition of Design Cycle, you and I are going to scratch-design a plug-in USB converter module based on the MCP2200. After we bring the MCP2200 hardware to life, we'll configure the MCP2200 and put it to work in front of the UART of a USB-challenged microcontroller.

MCP2200 ORIENTATION

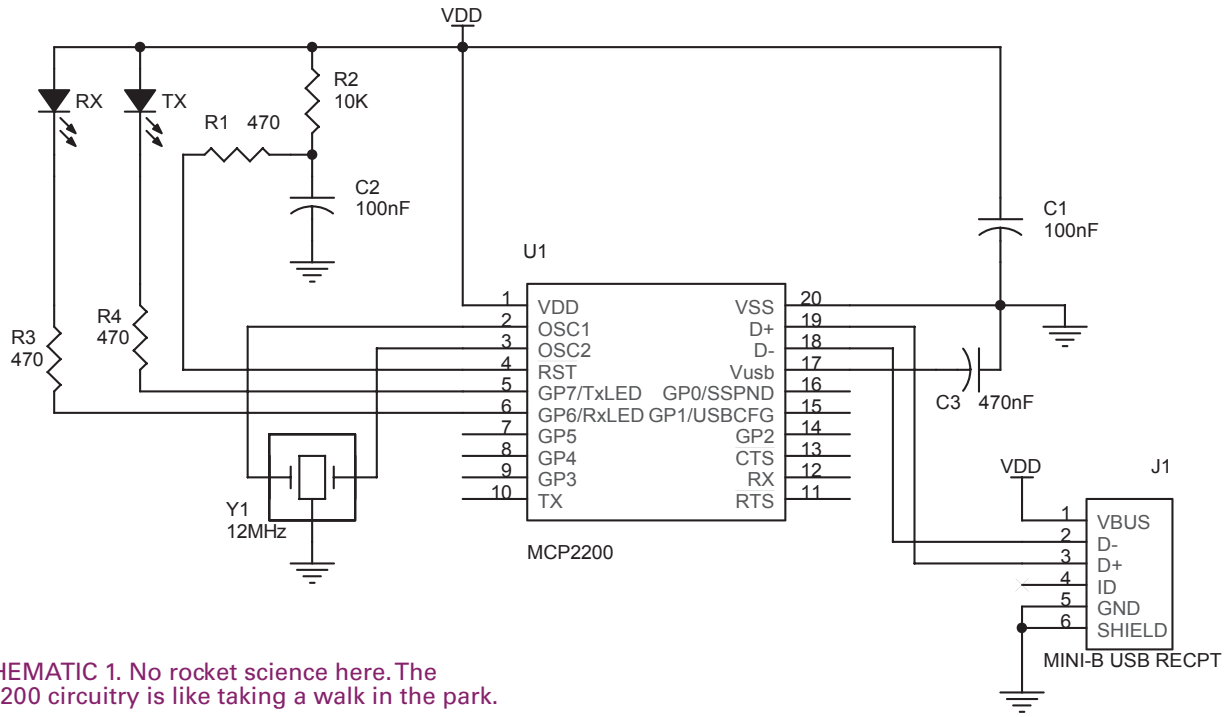
In addition to SOIC, the MCP2200 can be had in QFN and SSOP packages. If you're a hobbyist, chances are you don't have the necessary soldering tools to lay down tiny leadless QFN packages. The chances are also slim as to a hobbyist's toolability to accurately place and hand-solder SSOP parts. So, I've chosen to develop our MCP2200 design around the larger and easier to handle 20-pin SOIC package which can be easily placed and hand-soldered.

The MCP2200 is designed to support full speed 12 Mbps USB applications. If you go back a few issues (*Nuts & Volts* June '09 to be exact), you'll see that we've been actively pursuing USB trickery as it pertains to RS-232 for some time now. In the June '09 Design Cycle, we used a PIC low pin count USB development kit to form the basis of a USB CDC (Communications Device Class) device. The MCP2200 is also a USB protocol composite CDC device. One logical portion of the MCP2200 is a HID-class device and the other part is a CDC device. Thus, we will need to supply a driver for the CDC device. Recall that HID-class device drivers are part of the operating system. Not to worry. We won't be writing any MCP2200 CDC driver code as Microchip provides the necessary drivers.

The MCP2200 differs from the low pin count PIC18F14K50 we used in June '09 in that the MCP2200 is a dedicated USB device and cannot be programmed to run user-specific application firmware. For instance, we had to program the PIC18F14K50 to activate an I/O pin when it successfully enumerated to the CONFIGURED USB state. In the PIC18F14K50 design, we used the activated I/O pin to enable a 5.0 volt voltage regulator which provided power for auxiliary five volt electronic devices. We can perform the same "activate I/O pin when configured" functionality by simply utilizing the MCP2200's USBCFG status pin.



■ FIGURE 1. It looks like a PIC, kinda acts like a PIC, but it ain't officially a PIC. At least the datasheet says it ain't one.



■ SCHEMATIC 1. No rocket science here. The MCP2200 circuitry is like taking a walk in the park.

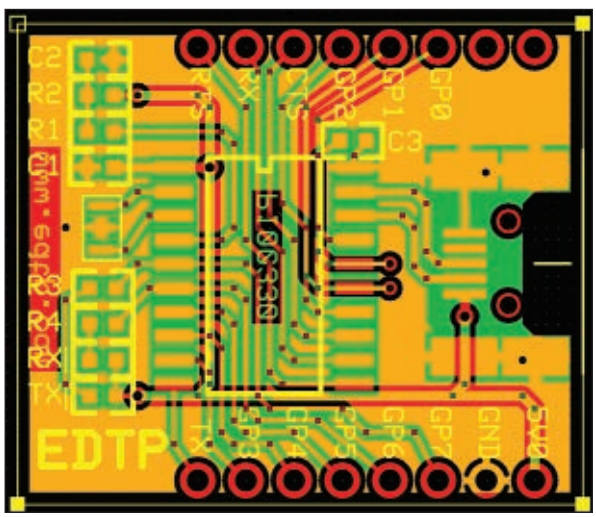
A high-level block diagram of the MCP2200 is depicted in **Figure 1**. The MCP2200 sure looks like a "specialized" microcontroller. However, I can't yet prove that it is. So, let's take a walk around its pins.

The MCP2200 can operate with voltages between 3.0 volts and 5.5 volts. In that most low power embedded applications that will employ the MCP2200 draw their power directly from the USB portal, the MCP2200 will find itself powered by the USB portal's 5.0 volt V_{BUS} line in most instances. This mode of operation is termed Bus Power Only mode in the MCP2200 datasheet. The MCP2200 can also be configured in self-powered mode.

I have this microcontroller feel about the MCP2200. One thing that really makes me think PIC is the MCP2200's need for an external 12 MHz quartz crystal or ceramic resonator. However, my "It's really a PIC" theory could be debunked by getting up on my donkey and declaring the clock signal is needed for the USB interface and/or the MCP2200's internal controller. Judging from the oscillator block in **Figure 1**, I'm willing to bet that the 12 MHz clock signal is processed through a 4x PLL to synthesize a 48 MHz USB clock. I'm also betting the farm on the control block really being a microcontroller block as it supports the configuration registers (SFRs in the PIC world), EEPROM, and GPIO. I'll get down off my donkey and continue our ceramic oscillator tale. The MCP2200 datasheet calls out a muRata CSTCE12M0G15L; the MCP2200 Demo Board User's Guide specifies a muRata CSTCE12M0G15L99-R0. I couldn't find either of those ceramic oscillators that I didn't have to buy 3,000 of. So, I finally came up with a muRata CSTCE12M0G55-R0 (Digi-Key part number 490-1197-1-ND) that we will use in our design.

Here we go again. Take a look at **Schematic 1**. Doesn't that arrangement of R1, R2, and C2 look like it could hang from a PIC's MCLR pin? The datasheet says we can sack C2. However, it's a good idea to have it in our design as it doesn't interfere with the operation of the MCP2200's internal POR circuitry. If you're absolutely sure your MCP2200 design will be driven by a host microcontroller with an available I/O line, you can dispense with the R2/C2 combination and drive the MCP2200's active-low RST pin directly from a microcontroller I/O pin.

If you've ever read a Design Cycle column, you know that I LOVE to blink LEDs. The MCP2200 I/O pins that interface to the LEDs in our design are part of its GPIO module. Like a microcontroller, the MCP2200's GPIO module is a standard eight-bit port. (Hmmmm ... looks like a microcontroller and is beginning to smell of one too.) Some of the GPIO module's I/O pins have alternate functions; this includes



■ SCREENSHOT 1. We could shrink this design considerably by replacing the SOIC with a QFN and reducing the SMT component size from 0603 to 0402. However, I think it's small enough right now, thank you.

the GP7/TxLED and GP6/ RxLED I/O pins. The blink pulse width of the TX and RX LEDs is configurable. In fact, you can configure the TX and RX LEDs to toggle on each message which allows your application to count incoming and outgoing messages by simply counting the LED toggles.

While we're on the subject of alternate GPIO pins, GP0 doubles as the USB suspend status pin. When the USB link goes into suspend mode, the MCP2200's USB suspend status pin can be used as a signal to put the entire device into low power mode. We briefly touched on the use of the MCP2200's USBCFG pin which is the alter ego of GPIO pin GP1. GPIO pins GP2 through GP5 are single-minded GPIO pins with no ulterior motives.

Years ago, I wrote an interrupt-driven UART receive/transmit routine that buffered incoming and outgoing bytes. I still use that code today. The idea was to not miss an incoming byte due to a more important process that happened to be taking up the CPU's time at that moment. On the transmit side, the CPU could post a byte to be transmitted into the buffer and return to business as usual without having to immediately worry about walking the byte through the entire transmission process. In that we can't code the MCP2200 and RS-232 I/O data buffering is important in high throughput applications, the MCP2200 engineers built a 128-byte buffer into its innards. The MCP2200's UART buffer is equally divided into 64 bytes for transmit and 64 bytes for receive operations. With the assistance of the UART buffer, the MCP2200 can support baud rates between 300 and 1 Mbps on its TX and RX pins.

In the golden days of the BBS masters, one had to be familiar with modems and modem control lines. Back then, it was a must to know that the DTR (Data Terminal Ready) signal had to trigger a DSR (Data Set Ready) signal from the modem before anything else could happen. If you were the "master" of a popular BBS, the RI (Ring Indicate) signal was a constant modem companion. RTS (Request To Send) and CTS (Clear To Send) are still in use today as hardware flow control signals for embedded devices. With that, the MCP2200's I/O subsystem and hardware flow control logic are equipped to handle situations where RTS/CTS hardware flow control is employed.

In the case of RTS/CTS flow control MCP2200 style, the MCU host's active-low CTS input is connected to the MCP2200's active-low RTS output. This active-low RTS signal is used by the MCP2200 to signal the host device that it can receive data. If the host gets chatty, the MCP2200 will raise the RTS signal one byte short of filling its buffer (63 bytes).

The MCP2200 CTS input is connected to the host MCU's active-low RTS output. When the MCP2200 sees its CTS input go logically low, it will send data. Once the send operation is initiated, raising the CTS signal will not abort the transfer that is in progress.

If the MCP2200 flow control mechanism is disabled, the buffer pointer does not increment. Without the guidance of the buffer pointer, the buffer can be overrun. The result of an MCP2200 buffer overrun is that the new data will overwrite the last position of the buffer.

Okay. Now that you have a rough idea of the MCP2200's capabilities, let's build that MCP2200 dongle.

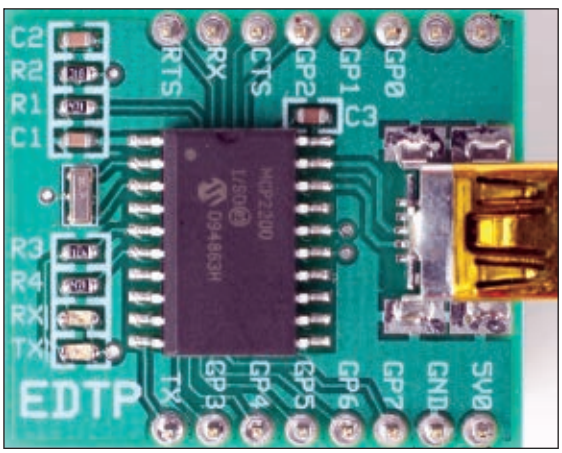
AN MCP2200 HARDWARE DESIGN

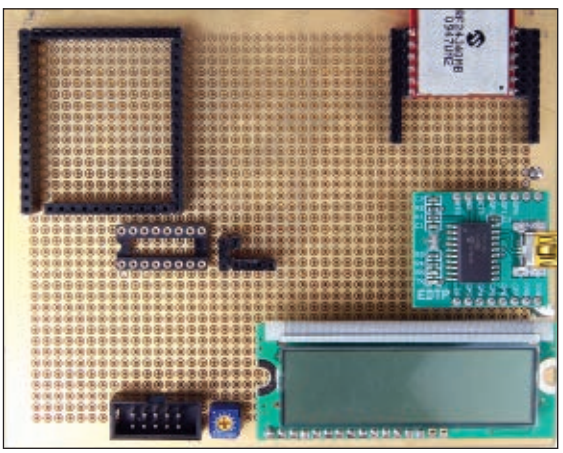
The MCP2200 USB-to-UART converter design outlined in **Schematic 1** could easily be adapted to a breadboard. However, the SMT components lend themselves to being mounted on a specialized printed circuit board (PCB) like the one you see on the drawing board in **Screenshot 1**.

There's not much I can tell you about assembling the MCP2200 USB-to-UART converter that you don't already know. As with any electronic project, keep your mind glued to the details to avoid releasing the magic smoke. There are no component polarity gotchas in this design as all of the capacitors are nonpolarized ceramic types. You do need to be careful when mounting the MCP2200 as you must pay attention to the correct orientation of pin 1 of the MCP2200. If your LEDs fail to blink, check to make sure that the cathodes of the LEDs are on the bar sides of the LED pads. The LED cathode bars are just to the right of the RX and TX silkscreen legends.

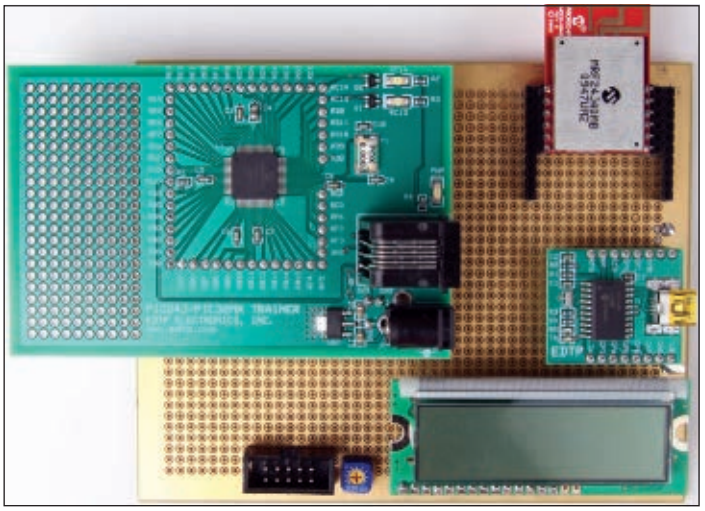
The MCP2200 USB-to-UART converter headers are on 0.1 inch centers and will mate with any standard breadboard or solderless breadboard similarly pitched. A fully assembled MCP2200 USB-to-UART converter with header pins is

■ PHOTO 1. Here's a fully assembled MCP2200 USB-to-UART converter reporting for duty. All of the GPIO pins and the TX and RX pins are terminated at a header pad. There's even a five volt header pad that makes the five volts supplied via V_{USB} available to external circuitry.





■ PHOTO 2. If you've been keeping up with Design Cycle and *SERVO Magazine*, you're already familiar with this piece of golden perfboard. I've removed the SP3232 RS-232 converter IC and replaced it with our MCP2200 USB-to-UART converter design.



■ PHOTO 3. Here's the whole shebang. A MCP2200 USB-to-UART converter-equipped PIC24FJ/PIC32MX Trainer in command of an MRF24J40MB 802.15.4 transceiver and an LCD.

shown in **Photo 1**. The idea behind the MCP2200 is to replace legacy RS-232 installations. The board you see in **Photo 2** used to have an SP3232 RS-232 converter IC in that empty socket. I installed the new MCP2200 USB-to-UART converter with only four connections. The converter's TX pin connects to the PIC24FJ128GA006's UART RX pin, and the PIC24FJ128GA006's UART RX pin crosses over to the converter's TX pin. The MCP2200 converter's five volt power and ground connections complete the connection quartet. The entire design pictured in **Photo 3** is graphically displayed in **Schematic 2**. Everything hardware is in place. So, let's plug a USB cable into the MCP2200 USB-to-UART Converter and see what happens.

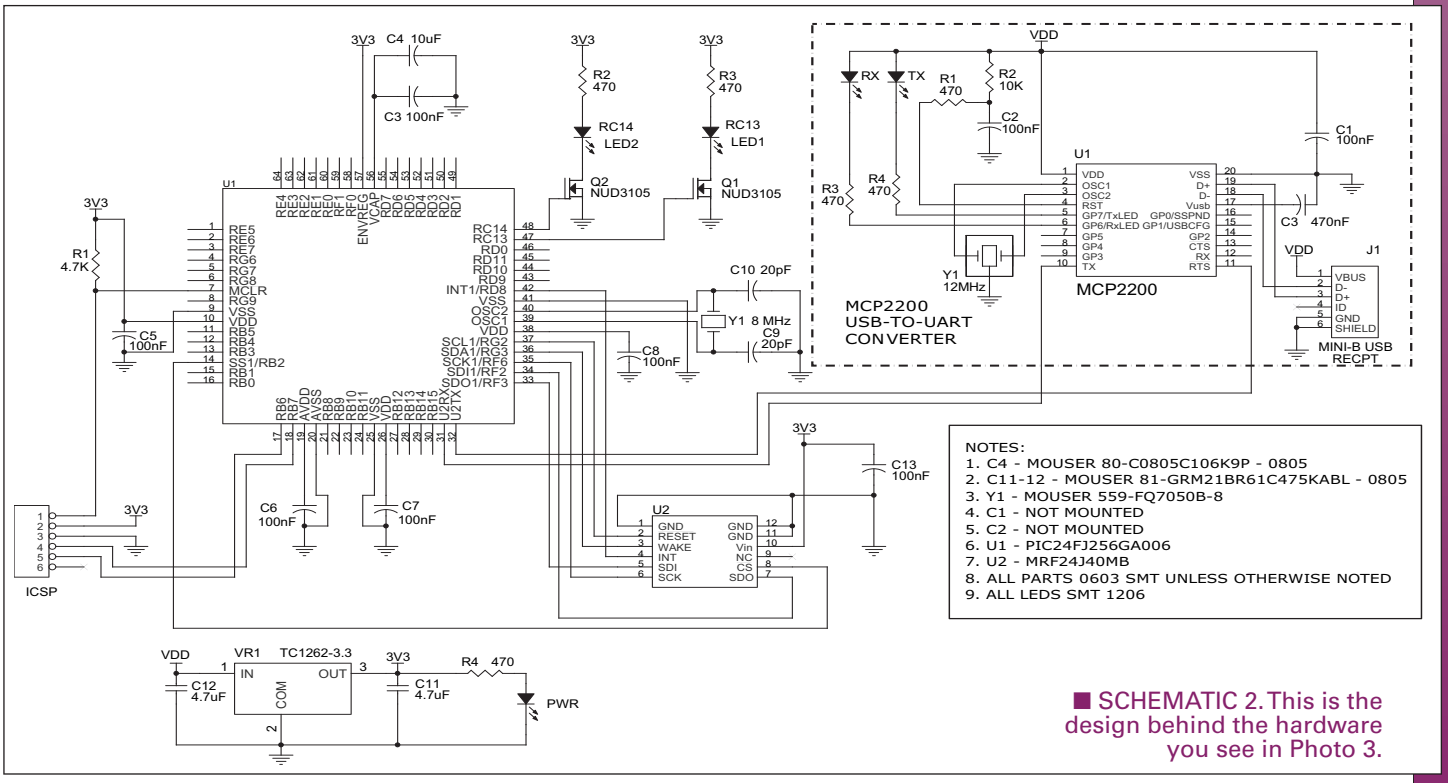
THE MCP2200 CONFIGURATION UTILITY

After attaching a USB cable to the MCP2200 USB-to-UART converter, I fired up the Configuration Utility and captured the main configuration window in **Screenshot 2**. The default VID (Vendor ID) and PID (Product ID) belong to Microchip. Obviously, if you owned your own VID and PID, you would enter them here.

If you were to expand the Baud Rate menu, you would find the highest baud rate value is 921600. The list of baud rates between 9600 and 921600 are the standard fare as far as baud rates go. For the purposes of our discussion, 9600 bps is plenty fast.

Once again the MCP2200 is starting to really look and feel like a PIC. The I/O config field is an eight-bit mask. A logical 0 says that the bit position is an output while a logical 1 sets the associated bit location as an input. Funny, that's exactly how PIC TRIS registers work. The Output Default window sets the logical output of any MCP2200 GPIO pin defined as an output pin in the I/O config field.

The rest of the Configuration Utility is intuitively obvious to the most casual observer. The alternate GPIO pin selects live in the upper right corner. I pulled the trigger on the displayed configuration in **Screenshot 3**. Before we leave the Configuration Utility, note that we can invert the UART signal polarity. The UPOL selection saves hardware by eliminating the need to place inverters in the UART signal path. I've seen some devices that do indeed want an inverted UART signal set.



■ SCHEMATIC 2. This is the design behind the hardware you see in Photo 3.

THE BOTTOM LINE ... DOES IT WORK?

When I plugged that USB cable into the MCP2200 USB-to-UART converter, I was confronted by the usual "let's install a new USB device" jargon. After the driver automatons did their thing, I was granted access to a VCP (Virtual Comm Port) and a HID device in the guise of our MCP2200 converter.

The easiest way to put some test code together is to call out the CCS C compiler. I whipped out the CCS C compiler 16-bit Project Wizard and quickly built a code shell for the PIC24FJ128GA006. Here are the Configuration Fuse settings which the Project Wizard generated and placed in the *nv-ccs-mcp2200-project.h* file:

```
#include<24FJ128GA006.h>

#FUSES NOWDT          //No Watch Dog Timer
#FUSES NOJTAG         //JTAG disabled
#FUSES NOPROTECT      //Code not protected from
                      //reading
#FUSES NOWRT          //Program memory not write
                      //protected
#FUSES NODEBUG        //No Debug mode for ICD
#FUSES ICSP2          //ICD uses PGC2/PGD2 pins
#FUSES NOWINDIS       //Watch Dog Timer in Window
                      //mode
#FUSES WPRES128       //Watch Dog Timer PreScalar
                      //1:128
#FUSES WPOSTS16       //Watch Dog Timer PostScalar
                      //1:32768
#FUSES NOIESO         //Internal External Switch
                      //Over mode disabled
#FUSES PR_PLL         //Primary Oscillator with PLL
#FUSES NOCKSFSM       //Clock Switching is
                      //disabled, fail Safe clock
                      //monitor is disabled
#FUSES NOOSCIO        //OSC2 is clock output
#FUSES XT             //Crystal osc <= 4mhz for
                      //PCM/PCH , 3mhz to 10 mhz
                      //for PCD

#use delay(clock=32000000)
```

The CCS C compiler is a wonderful PIC compiler. I was able to put together this simple converter test program in less than 15 minutes:

```
#include "C:\nv-ccs-16bit\nv-ccs-mcp2200-
project.h"
#use rs232(UART2,baud=9600,parity=N,bits=8)
void main()
{
    setup_spi( FALSE );
    setup_spi2( FALSE );
    setup_wdt(WDT_OFF);
    setup_timer1(TMR_DISABLED);

do{
       printf("THE MCP2200 IS NOW PART OF
       YOUR DESIGN CYCLE!!\r\n");
       delay_ms(500);
       }while(1);
}
```

The converter allows us to code our applications just as if they were using that SP3232 we replaced in the design. The proof is in the pudding and the pie crust is filled with **Screenshot 4**.

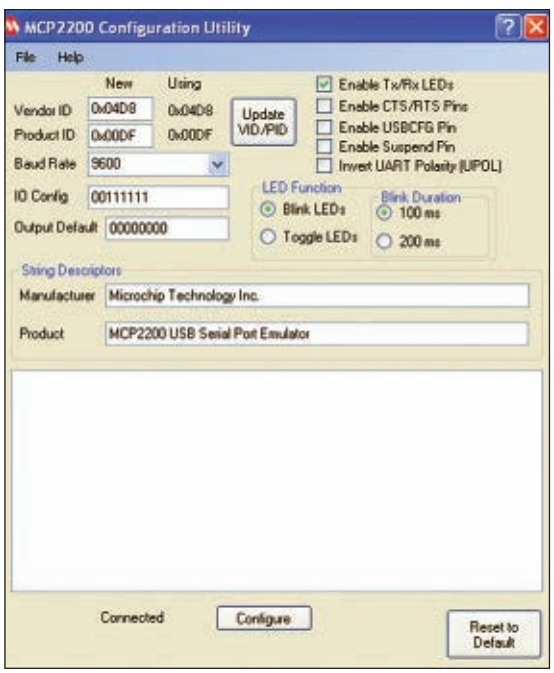
NO PORKY PIG QUITE JUST YET

As Jason Aldean says about all night redneck parties ... "We ain't done yet." I've got a Scooby-Doo ending for you. I'm going to leave you with some C30 source code that will address the LCD and make the RX LED on your converter blink with joy:

```
void initUART(void)
{
    U2BRG = 104;           //9600 bps
    U2MODE = 0x8000;       //enable the UART
    U2STAbits.UTXEN = 1;   //enable TX
}
```

The little initUART code snippet is all that's needed to configure the PIC24FJ128GA006's UART to drive at 9600 bps. If you're wondering why the MCP2200's RX LED would flash instead of its TX LED, the MCP2200 is on the USB side of things. As far as the MCP2200 is concerned, the PIC24FJ128GA006 is transmitting and it is receiving. The receive/transmit status reported by the MCP2200's RX and TX LEDS is not the PIC24FJ128GA006's status but its own status.

■ SCREENSHOT 2. To quote Joe Friday, "All we want are the facts, ma'am." That's pretty much all that the MCP2200 Configuration Utility really wants too.



■ SCREENSHOT 3. The only value I changed for our design was the baud rate which defaults to 19200 bps.

SOURCES

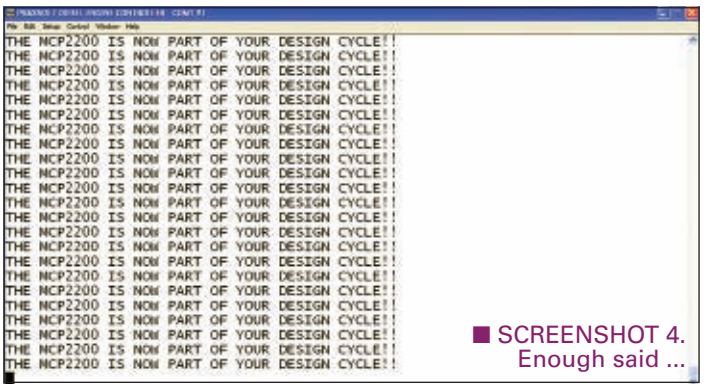
Microchip MCP2200 Microchip C30 C Compiler PIC24FJ128GA006 **www.microchip.com**	EDTP Electronics, Inc. PIC24FJ/PIC32MX Trainer MCP2200 USB-to-UART Converter **www.edtp.com**

Here's the rest of the picture:

```
char data_out;
int main(void)
{
        data_out = 0x20;
        //SETUP LEDS
        TRISCbits.TRISC13 = 0;
        TRISCbits.TRISC14 = 0;
        LED13_OFF();
        LED14_OFF();
        initUART();
        LCDInit();
        DelayMs(100);
        strcpy((char*)LCDText, " MCP2200      "
                               " USB-TO-UART");
        LCDUpdate();

        do{
        U2TXREG = data_out++;
        if(data_out > 'z')
         data_out = 0x20;
        DelayMs(100);
        }while(1);
}
```

Don't worry. I'll post all of the code to drive the LCD and the PIC24FJ128GA006's UART in our usual spot at **www.nutsvolts.com**. If those *strcpy* lines give you heartburn, code it like this:

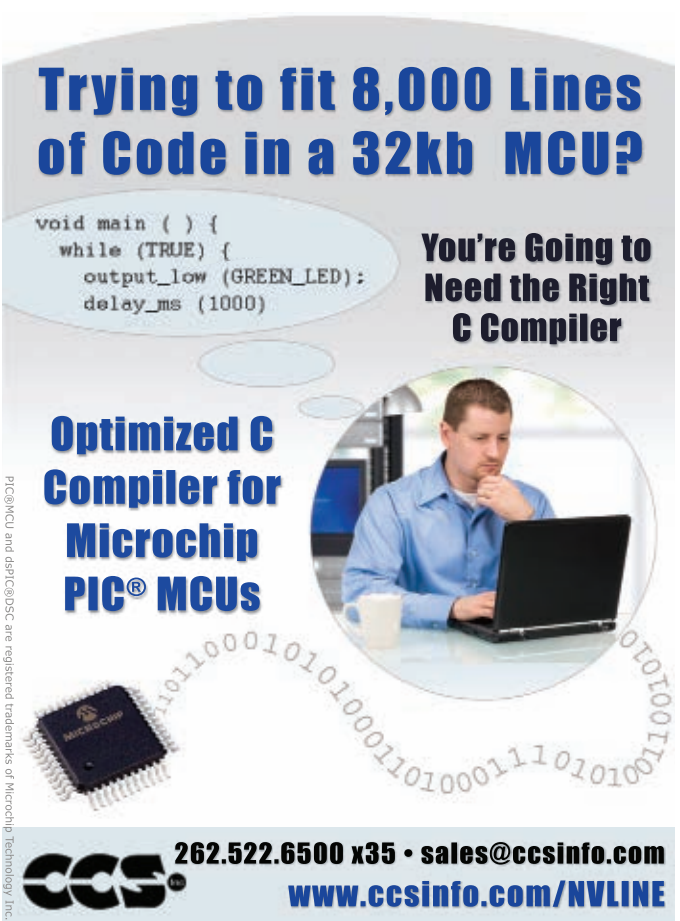


■ SCREENSHOT 4. Enough said ...

```
strcpy((char*)LCDText,
"     MCP2200        USB-TO-UART");
```

You'll get the same result on the LCD. The UART code that is spinning between the *do-while* braces will send every ASCII character between a space and the lower-case z, and start over again at the space character (0x20). Okay. Now that the MCP2200 is in your Design Cycle, we can cue Porky ... "Th-Th-Th-Th-Th- ... That's all, folks." **NV**

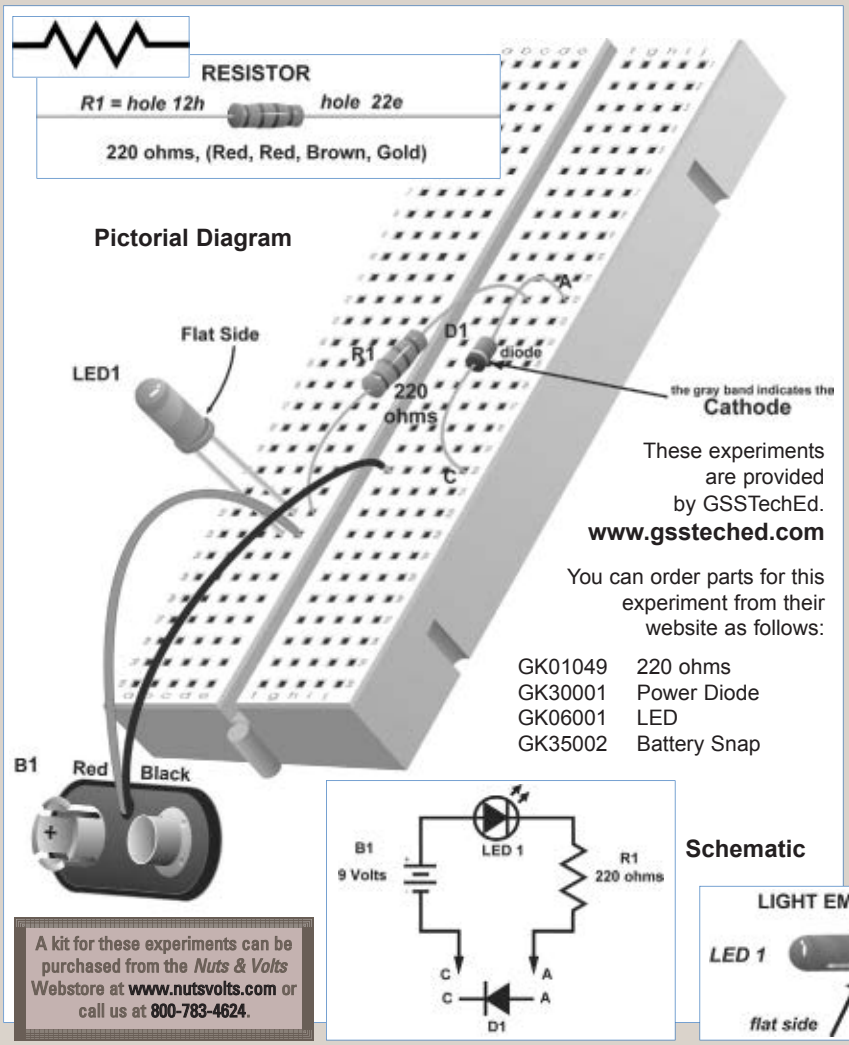
Fred Eady can be contacted via email at fred@edtp.com.



FUNDAMENTALS FOR THE BEGINNER

HOW A DIODE WORKS

A diode is a device that will let electrons flow through it in only one direction. This is very useful in electronic circuits to keep electrons from flowing where they're not supposed to. Diodes are also used in logic circuits in computers.



These experiments are provided by GSSTechEd.
www.gssteched.com

You can order parts for this experiment from their website as follows:

GK01049	220 ohms
GK30001	Power Diode
GK06001	LED
GK35002	Battery Snap

Schematic

A kit for these experiments can be purchased from the *Nuts & Volts* Webstore at **www.nutsvolts.com** or call us at **800-783-4624**.

1. Build the Circuit.

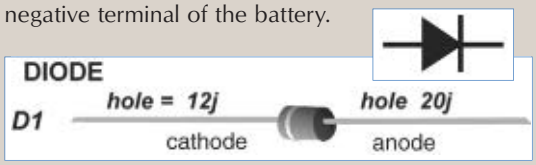
Using the schematic along with the pictorial diagram, place the components on a solderless breadboard as shown. Verify that your wiring is correct.

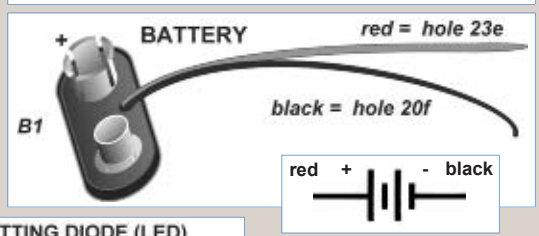
2. Do the Experiment.

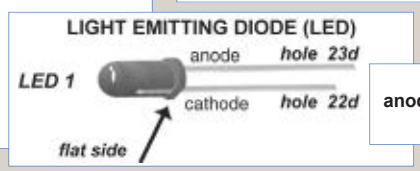
Theory: In this simple electronic circuit, the electrons flow from the battery through the diode, the resistor, the LED, and back to the battery.

Procedure: Connect a nine-volt battery to the battery snap and observe that the LED is lit, showing that current is flowing in the circuit. Now, take the diode out of the breadboard and put it back in with the color band on the opposite end. The LED will not light up.

The LED will only light up when the side on the diode with the color band is connected to the negative terminal of the battery.







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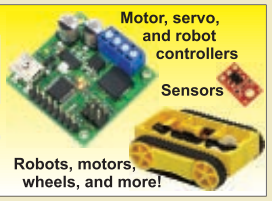

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BY L. PAUL VERHAGE

THEY CAME FROM OUTER SPACE!

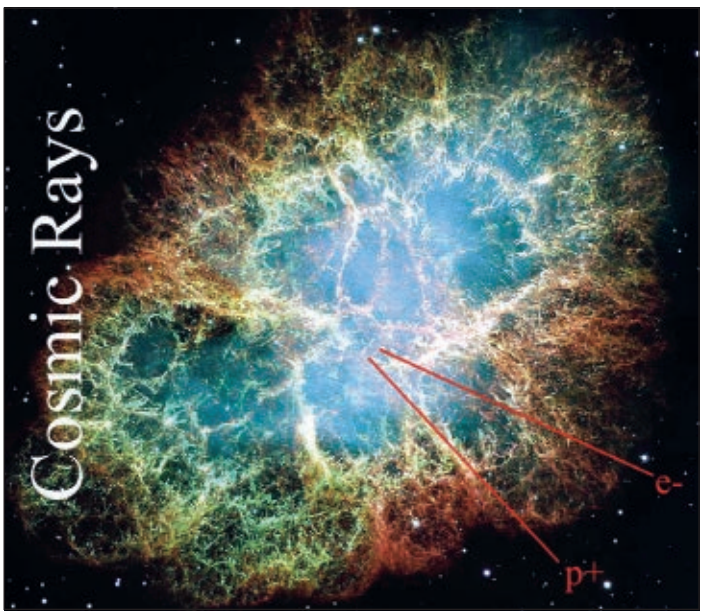
Atoms from another star and possibly from another galaxy are detectable right here on earth. What are these mysterious rays and how are they detected in near space?

THE DISCOVERY OF COSMIC RAYS

The Austrian physicist Victor Hess took a little balloon ride in 1911 to discover the source of a mysterious radiation. Previously, physicists had assumed this radiation originated from elements on earth, but they were yet to localize its source. They believed it originated from the earth because early experiments indicated the radiation decreased as one ascended in altitude. That's what's expected if its source was indeed the earth. Hess' experiment was designed to measure the background radiation level as his balloon carried him higher and verify if its source was terrestrial or cosmic.

In 1911, one of the few instruments capable of accurately measuring radiation levels was the electroscope. You'll recall that an electroscope consists of a container with an electrode on the top. Inside the container and attached to the electrode are two thin metal foil leaves. By bringing a charged object near an electroscope, the electroscope's two leaves acquire a charge. The electric charge on both leaves is the same and since like-charges repel one another, the leaves spread apart. Over time, the leaves fall back together. "Where does the charge go to?" asked the physicists. They discovered that radioactive substances are capable of neutralizing the charges, keeping the leaves spread apart. They also discovered that the greater the "strength" of the radioactive material, the quicker the leaves fell back together. By measuring how quickly the charged electroscope leaves fell back together, Hess was able to measure the amount of background radiation as he ascended in his balloon.

Hess rode balloons both day and night, during a solar eclipse, and up to altitudes of 17,000 feet (which can be dangerous). He discovered that the background radiation decreased for the first 3,000 feet of the ascent. That's expected — if the mysterious background radiation originated from radioactive elements in the earth's crust.

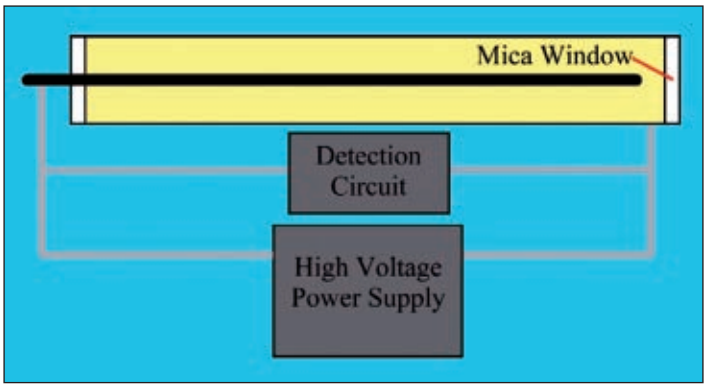


Hess then observed that above 3,000 feet, the background radiation began increasing with altitude. This indicated a source of radiation originating from space and that the radiation for the first 3,000 feet is just from uranium and thorium in the earth's crust. American physicist Robert Millikan (he was the first to measure the amount of electrical charge in the electron) later confirmed this finding and gave the radiation the name we call it today: cosmic rays.

Experiments indicate cosmic rays consist primarily of energetic protons (the nucleus of the hydrogen atom) and other atomic nuclei. Thrown into the cosmic ray mix are electrons and occasional gamma ray photons. Because cosmic rays consist primarily of energetic subatomic particles rather than photons, it's not correct to call them rays. However, because of historical precedence, we still refer to them as such.

The ratio of protons to heavier nuclei in cosmic rays matches the ratio of elements found in the sun. Therefore, the source of cosmic rays must be objects like stars. What is responsible for giving cosmic rays their tremendous energy? The first attempts to measure their direction of travel indicated cosmic rays appear equally in all directions. This shouldn't be surprising; the magnetic fields between their source and the earth will deflect, reflect, and scramble the paths of cosmic rays. Fifty years ago, Italian physicist Enrico Fermi hypothesized that interstellar

■ Consisting of just two thin metal foil leaves, the electroscope was the first instrument capable of making quantitative measures of electrostatic fields and radiation. The small bag inside this electroscope contains a desiccant to reduce the effects of humidity on the charge the leaves hold.



■ A simplified diagram of a Geiger counter. The steel wall of a GM tube blocks most alpha particles. So, alpha-sensitive GM tubes have a thin mica window where alpha radiation can penetrate the tube.

magnetic fields were responsible for giving cosmic rays their energy. A potential source of powerful magnetic fields is available inside young supernovae remnants (SNRs) like the Crab Nebula pictured at the beginning of this article. Astronomers have been trying for years to detect signs that SNRs like the Crab are turning subatomic particles into cosmic rays.

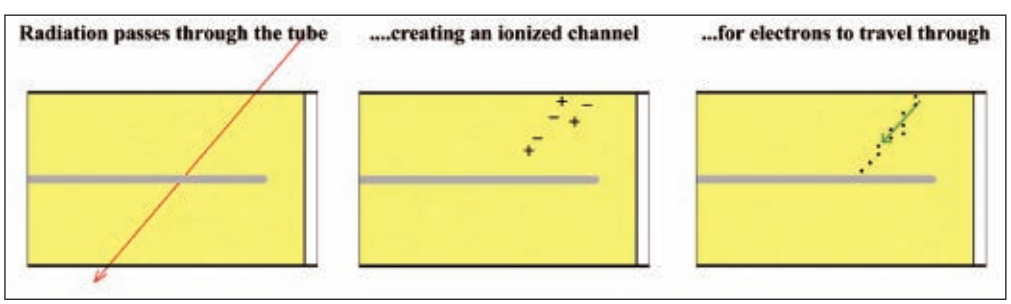
This year, the Fermi Gamma Ray Space Telescope detected very energetic gamma radiation emanating from younger SNRs and lower energy gamma radiation emanating from older SNRs. How energetic are we talking about? Photons of visible light have one or two electron volts (EV) each of energy. The gamma ray photons Fermi detected are a billion times more energetic. The gammas Fermi measured most likely originated when energetic cosmic rays collided with the atoms of cold interstellar gas clouds. The gamma rays are then a proxy for the cosmic rays we can't detect coming from supernovae remnants.

The fact that higher energy gamma rays originate in younger SNRs indicates their more powerful magnetic fields are trapping cosmic rays longer (as SNRs age, their magnetic fields become weaker). The longer subatomic particles remain inside the remnant, the more they cross shockwaves inside the remnant. Each passage through a shockwave increases their energy. Once a particle gains too much energy for the SNR's magnetic field to hold on to it, it escapes to become a cosmic ray. The newly minted cosmic ray travels around the galaxy in a path deflected by the magnetic fields it encounters. Therefore, the detection of a cosmic ray is a detection of an atom from another star. However, we have to climb high to detect a real cosmic ray. Cosmic rays entering earth's atmosphere collide with molecules like nitrogen and oxygen. The collision between a cosmic ray and a molecule shatters the atoms inside the molecule to create additional cosmic rays. To distinguish between them, the original cosmic ray is called a primary and the additional cosmic rays created in the collision are called secondaries. In his balloon experiment, Hess was actually measuring the flux of secondary cosmic rays. Hess measured more secondaries at higher altitudes because after their creation, secondaries continue to lose energy through collisions as they dive through the atmosphere. Only a small number of primary and secondary cosmic rays are detectable from the ground. A near space balloon flight, however, can ascend above most of the secondaries to begin detecting the original primaries. Instead of carrying an electroscope and measuring how quickly its leaves discharge, a near spacecraft carries a Geiger counter.

THE GEIGER COUNTER

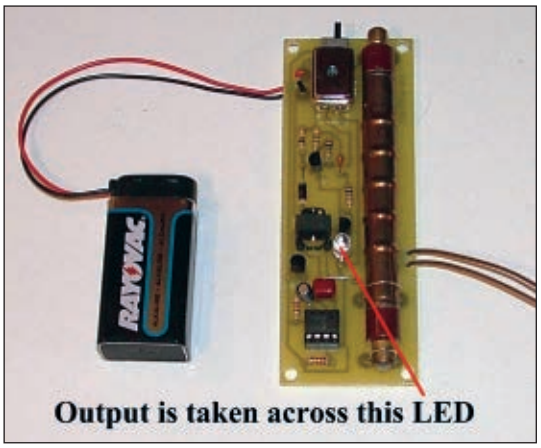
The Geiger counter was a great improvement over using the electroscope to detect radiation. Initially developed by Hans Geiger and Ernest Marsden in 1911, it was later improved by Geiger and his student, Walther Muller in 1928. A Geiger-Muller (GM) tube is the heart of the Geiger counter and it consists of a metal tube filled with a low pressure gas. The gas usually includes a mixture of halogens and/or hydrocarbon gasses. There is a wire running through the tube. The metal tube and inner wire are connected to a high voltage power supply (400 volts is not uncommon). Monitoring the voltage across the tube is a detector circuit.

Until ionizing radiation passes though the GM tube, current cannot flow between the wall of the tube and its central wire — the tube behaves like an open switch and voltage across the tube remains at several hundred volts. Ionizing radiation like alphas, betas, and gammas are dangerous because they can strip electrons off atoms (ionize them), encouraging hazardous chemical reactions inside our



■ Ionizing radiation ultimately creates a conductive channel inside a GM tube. Note that radiation like microwaves is not ionizing, and passes through the tube without triggering a detection.

cells. It's the ionization created by radiation that lets current flow through the GM tube. The flow of electrons through the GM tube further ionizes the gas inside. The ionized channel — conductive to electrons — makes the GM tube behave like a closed switch. When closed, the voltage drop across the GM tube is closer to zero volts. This reduction in the voltage drop across the tube is the detection of radiation. The detector circuit displays the results as an audible click, a flashing light, or it counts and graphically displays the number of detections per minute on an indicator.



■ The Electronic Goldmine Kit.

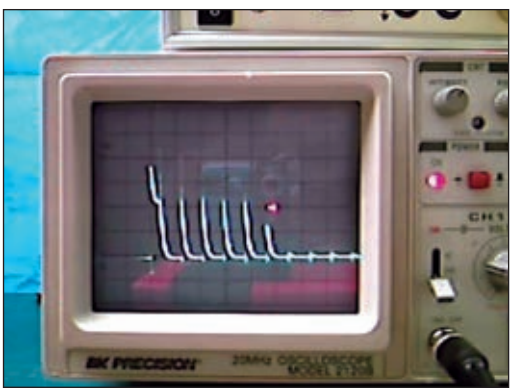
GM tubes are quenched. Without quenching, the first detection of radiation will lead to so much ionized plasma inside the tube that current will keep flowing through the tube. Quenching gasses inside the GM tube eventually absorb the energy of the free electrons. The electrons can then recombine with the ionized atoms to reform a neutral gas and the GM tube is ready to detect radiation again. Until the electrons recombine, the GM tube is incapable of detecting additional radiation. This period of time is called the dead time of the tube and is on the order of microseconds for a good quality GM tube.

TWO GEIGER COUNTERS I'VE USED IN NEAR SPACE

When I began preparing to explore near space, I looked at three different Geiger counters. In the process, I destroyed two of them. I was left with the RM-60 — a laptop-capable Geiger counter made by Aware Electronics (**www.aw-el.com**). The RM-60 plugs into a serial port where it receives power (five volts) and sends a zero volt pulse every time it detects radiation. If you read my article on the Geiger Counter Telescope, then you're familiar with this device and why I love it. Now, I'd like to share with you my experience with a different Geiger counter.

Earlier this year, I ordered a Geiger counter kit from Electronic Goldmine (**www.goldmine-elec.com**). It was on special for $70 so I thought I'd give it a try. The Geiger counter uses a Russian-made GM tube and that's probably why it's as inexpensive as it is. The kit's directions are well written and I found it an easy kit to assemble. After looking at the schematic that came in the directions, I decided to measure radiation by counting the voltage pulses across the green LED with a PICAXE.

Counting voltage pulses across the LED was simple. However, when I did this, the number of detections of radiation was absolutely huge (in fact, impossibly large). This called for further investigation, so I connected an oscilloscope across the LED leads.

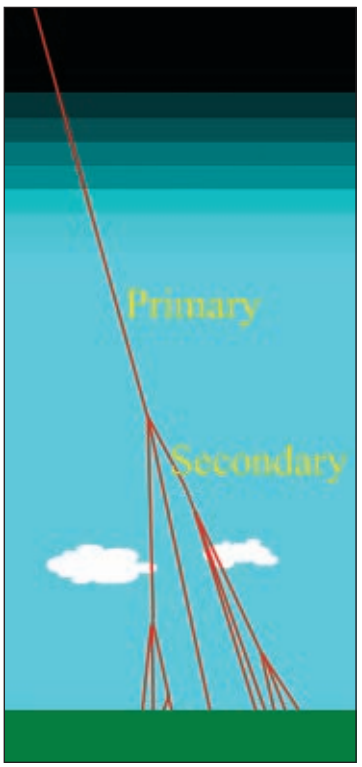


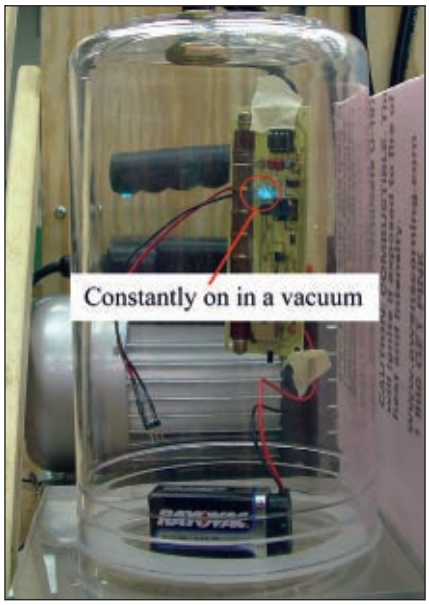
■ A screen capture from a video made of the oscilloscope display.

The oscilloscope showed five or six pulses per cosmic ray detection. The reason is that the power supply for this Geiger counter consists of a 555 timer and small inverter transformer. The output voltage is not filtered with a capacitor, so the GM tube receives its high voltage in a square wave. According to the oscilloscope, the voltage spikes of a detection are four volts at a frequency of 200 Hz. Therefore, to use this Geiger counter, we'll have to divide the counts detected by five or six.

Mike Manes, from Edge of Space Sciences, recommended first placing the Geiger counter into a vacuum chamber before sending it into near space. That's to verify it doesn't suffer from corona discharge. Corona discharge occurs when high voltage finds a way to arc across a circuit. At sea level, air pressure isn't usually an issue because the air has sufficiently high resistance. In a near vacuum, it's another story. Without insulating air, high voltage electrons can jump across a large gap to create a short circuit. Corona discharge would probably result in a Geiger counter stuck in

■ Rays in the atmosphere.





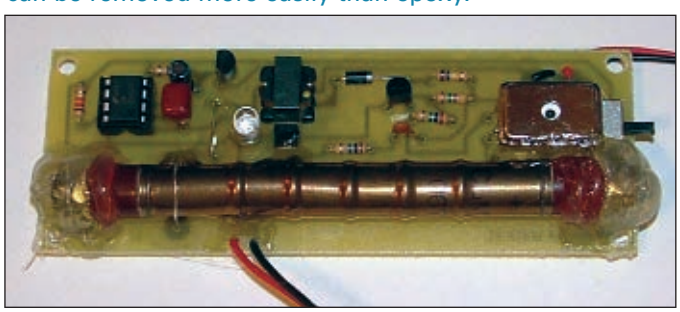
■ This LED should be flashing, rather than remaining on constantly.

the ON position. That is, it would produce a continuous signal rather than the click-click of cosmic ray detections. So to be sure, I loaded the Geiger counter and nine volt battery into the clear plastic jar of my environmental test chamber and pumped it down. Initially, the Geiger counter behaved as normal, giving the occasional click as the chamber was brought to a vacuum. Then, around 28 inches of vacuum (roughly 70 mb of pressure), the indicator LED began flashing faster until it remained on constantly. Oops, corona discharge. Corona discharge can be a real pain to locate because it often can't be seen. I initially assumed the discharge was occurring from the high voltage traces on the underside of the PCB. I applied a liberal coat of hot glue over these traces and exposed the Geiger counter to the vacuum a second time. It was still arcing, but at a lower pressure now, so hot glue was covering up some of the problem. On the second fix, I coated both ends of the GM tube in hot glue and tried again. That did it; I could pump the vacuum chamber to as high of a vacuum as my pump could handle without the Geiger counter suffering from corona discharge.

FLIGHT RESULTS WITH THE NEW GEIGER COUNTER

Last April 17th, I launched my first near space flight of 2010 in conjunction with the University of Kansas. The AE360 class — Introduction to Aeronautical Engineering — had built BalloonSats and was ready to fly them. I provided two tracking capsules as the student BalloonSats did not contain GPS receivers or radios. (I like to think I'm providing the Space Shuttle that students are flying their experiments onboard.) The flight reached 102,500 feet and landed in a tree, about 40 feet above the ground.

■ Not pretty, but hot glue is very insulating. Best of all, it can be removed more easily than epoxy.



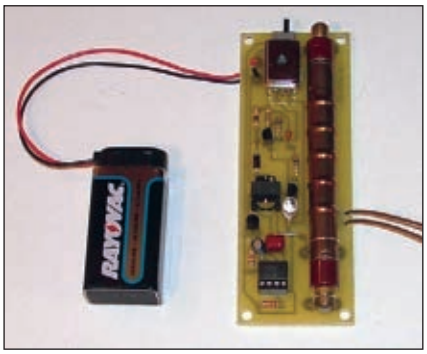
Along with a weather station and camera, I flew the RM-60 and Electronic Goldmine Geiger counters. The number of detections (clicks) from both units was counted for 10 seconds at 30 second intervals. I converted the counts for each detector into counts per minute and graphed the results. The first thing to notice is that the Goldmine Geiger counter always detects more radiation than the RM-60 (even when its multiple pulses per detection are taken into consideration). Even on the ground, there are more detections by the Goldmine Geiger counter. Why this is the case, I'm not sure. Aware Electronics makes a calibrated Geiger counter that's suitable for serious studies, so I trust the numbers of the RM-60.

Next, I noticed that the Goldmine Geiger counter detected a drop in the cosmic ray flux for the first 3,000 feet. This is pretty much what Hess detected. Above 3,000 feet, the cosmic ray flux increased as the altitude increased for both Geiger counters. This was also expected as there is less air to filter secondary cosmic rays as the balloon climbs higher. Around 62,000 feet, the flux dropped off as the balloon began sampling more primary cosmic rays before they could create a secondary shower. The RM-60 Geiger counter had always shown this peak, however, the other Geiger counter showed it weakly, if at all. What about that drop-off that begins at 101,000 feet? It looked too substantial to be a glitch or random variation. To clear that up, I'm going to have to fly the Geiger counters again.

WHAT DOES IT MEAN?

After some discussion with near space groups on GPSL, we figured the Goldmine Geiger counter GM tube has a larger volume and therefore detects more radiation

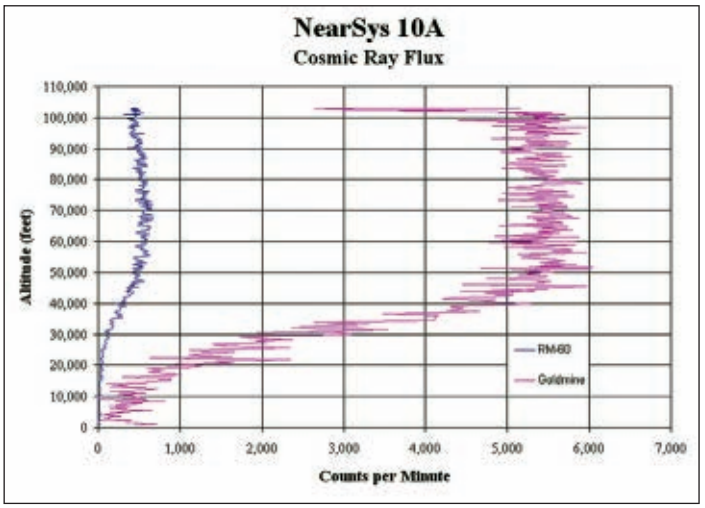
■ Trees are near space magnets. There was plenty of open space around our recovery site, but against the odds, we landed in a tree too high to climb. Now, where is that rope?



■ The Goldmine GM tube.

than the RM-60. Perhaps, but the volume isn't large enough to account for rates as high as we see. It was also brought up that the increased counts could be an instrumentation effect. If so, then a variation of the circuit or mathematical manipulation in the spreadsheet could offset the errors. I also wondered if the GM tube had failed in the near vacuum or if corona discharge occurred. I ran the Goldmine Geiger counter through the vacuum chamber once again and observed that it was still performing fine. My discussions with Aware Electronics made me "aware" that some Russian GM tubes are pretty old. The tubes may be fine at qualitatively showing radiation changes, but not suitable for quantitative work. So, for an inexpensive way to show how cosmic ray flux changes with altitude, the Goldmine kit may be fine for a BalloonSat where low cost is an issue.

So, next on my list is to design a Geiger counter for BalloonSats. I want one that's relatively inexpensive, small, and lightweight. I think I'll incorporate a PICAXE-08 to do the counting and allow the BalloonSat's flight computer to focus on doing other tasks. You can stay up to date with my exploits and experiments either at Twitter (#NearSys), my webpage (**NearSys.com**), my YouTube channel (**www.YouTube.com/NearSys**), or my occasional blog entry (NearSys.blogspot.com).



■ Cosmic ray flux.

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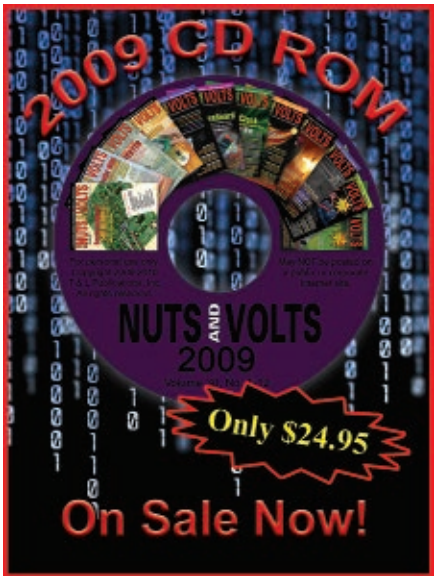
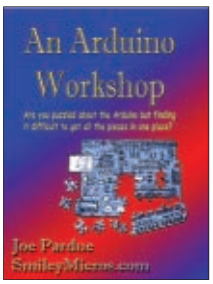


ELECTRONICS

An Arduino Workshop
by Joe Pardue



The Arduino — designed for the novice — has become so popular that there is now an embarrassment of riches when it comes to the amount of information and hardware available. So much stuff is out there that some folks have trouble puzzle piecing out what they need to just get started. The author is known for his breezy writing style and lucid illustrations that help folks understand complex technical topics. For more information, please go to: *http://store.nutsvolts.com/home.php*
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TRON.IX Book 1
by Gary Gibson

Hands-On Electronics Experiments!

This is the beautiful, fully-illustrated manual for the hands-on lab to help you build 40 of the most interesting experiments you have ever seen on a solderless circuit board, and as you do, you learn how the basic components work in a circuit. You will enjoy hours of fun creating all kinds of sounds and light displays.
$14.95

Electricity Experiments
by Stan Gibilisco

Electricity Experiments You Can Do At Home is a hands-on guide that helps you master the principles of electrical currents and magnetism. Each of the book's three section — direct current, alternating current, and magnetism — begins with step-by-step instructions for setting up your lab for the experiments that follow. Using inexpensive, easy-to-find parts, the experiments progress from basic to more complex and will spark ideas and encourage inventiveness. **$24.95**

Encyclopedia of Electronic Circuits, Volume 7
by Rudolf F. Graf / William Sheets

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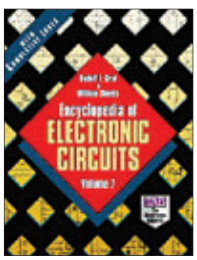
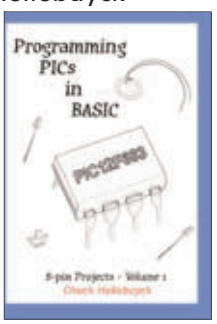


Designed for quick reference and on-the-job use, the *Encyclopedia of Electronic Circuits, Vol 7*, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. Organized alphabetically by circuit type, this all-new collection includes the latest designs from industry giants such as Advanced Micro Devices, Motorola, Teledyne, General Electric, and others.
$39.95

Programming PICs in Basic
by Chuck Hellebuyck



If you wanted to learn how to program microcontrollers then you've found the right book. Microchip PIC microcontrollers are being designed into electronics throughout the world and none is more popular than the 8-pin version. Now the home hobbyist can create projects with these little microcontrollers using a low cost development tool called the CHIPAXE system and the BASIC software language. Chuck Hellebuyck introduces how to use this development setup to build useful projects with an 8-pin PIC12F683 microcontroller. **$14.95**

Programming A Beginner's Guide
by Richard Mansfield

Essential Programming Skills — Made Easy!

This book will get you started right away writing a simple but useful program in Visual Basic Express Edition, and then moves on to more advanced projects, including a quiz program and a protected personal diary. You'll develop real-world programming skills, like designing user interfaces and working with variables, arrays, loops, and procedures. **$29.95**

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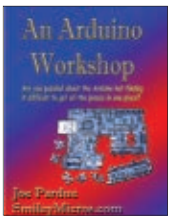
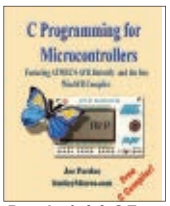


From the Smiley Workshop
An Arduino Workshop
by Joe Pardue

The book *An Arduino Workshop* and the associated hardware projects kit bring all the pieces of the puzzle together in one place. With this, you will learn to: Blink 8 LEDs (Cylon Eyes); Read a pushbutton and 8-bit DIP switch; Sense Voltage, Light, and Temperature; Make Music on a piezo element; Sense edges and gray levels; Optically isolate voltages; Fade an LED with PWM; Control Motor Speed; and more!

An Arduino Workshop Combo
Reg. Price $ 124.95 **Subscriber's Price $119.95 Plus S/H**



Book **$44.95**

From the Smiley Workshop

C Programming for Microcontrollers
by Joe Pardue

Kit **$66.95**

Do you want a low cost way to learn C programming for microcontrollers? This 300 page book and software CD show you how to use ATMEL's AVR Butterfly board and the FREE WinAVR C compiler to make a very inexpensive system for using C to develop microcontroller projects.

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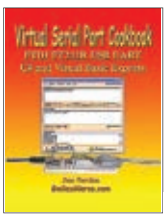

Virtual Serial Port Cookbook
by Joe Pardue
As talked about in the
Nuts & Volts June issue
"Long Live The Serial Port"

Book **$44.95**

Kit **$69.95**

This is a cookbook for communicating between a PC and a microcontroller using the FTDI FT232R USB UART IC. The book has lots of software and hardware examples. The code is in C# and Visual Basic Express allowing you to build graphical user interfaces and add serial port functions to create communications programs.

The Virtual Serial Port Combo
Reg. Price $ 114.95 **Subscriber's Price $109.95 Plus S/H**

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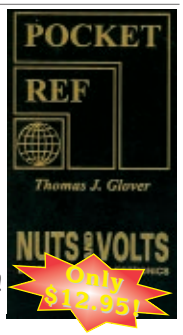
This great little book is a concise all-purpose reference featuring hundreds of tables, maps, formulas, constants, and conversions. AND it still fits in your shirt pocket!



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PROJECTS

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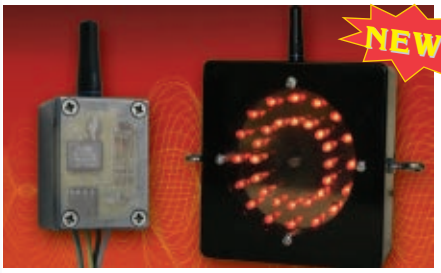

As seen on this month's cover!

This kit includes the custom parts you'll need to build your wireless taillight system. The custom parts include: one transmitter, two receiver PCBs, three programmed chips, and two plastic lens covers. Never wire trailer lights again!

Subscriber's Price **$45.95**
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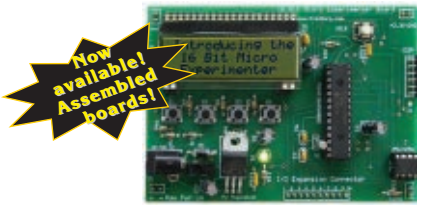
A complete kit is also available.

16-Bit Micro Experimenter Board



Ready to move on from eight-bit to 16-bit microcontrollers? Well, you're in luck! In the December 2009 *Nuts & Volts* issue, you're introduced to "the 16-Bit Micro Experimenter." The kit comes with a CD-ROM that contains details on assembly, operation, as well as an assortment of ready-made applications. New applications will be added in upcoming months.

Subscriber's Price **$55.95**
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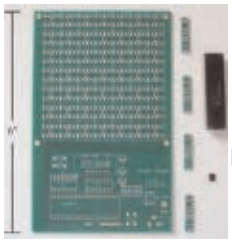
Indoor Shooting Range PCB & Programmed Chips



As seen on the May 2010 cover.

Build your own indoor shooting range! With a little part-customizing for your own weapon and components from your favorite parts house, you'll be firing photon bullets in no time. We have the printed circuit boards and the two programmed chips necessary for this great project available for your convenience. Includes an article reprint.

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PCBs can be bought separately.

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Using Neon and Nixie bulbs, this clock displays the precision movement of time and is programmable to display "Time Chaos" at different intervals. The NixieNeon Clock then resets itself to the correct time in an eye-catching ballet of luminosity. The PCB is 7.25"x 7.25" and consists of over 400 components.

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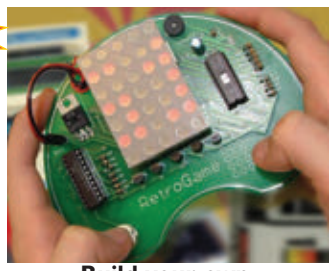
Now With New Code!

Retro Game Kit



Build your own "BLAST from the Past!"

This is sure to be a hit for all ages! Easy to build in an evening and will give you many more fun filled evenings mastering the Retro Rover or Retris games. Games come preprogrammed on individual MCUs

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This vehicle is coming straight from the future and is running on clean hydrogen fuel using a next generation reversible Polymer Electrolyte Membrane (PEM) fuel cell. The Hydrocar is used in a couple of great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 10 and 11, he teaches you the operation of the PEM "reversible" fuel cell. For kit details and a demo video, please visit our webstore.

Subscriber's Price **$79.95**
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rCube Talking Alarm Clock Kit

As seen on the May 2009 cover

Available in blue, black, red, and green. All components are pre-cut & pre-bent for easier assembly and the microcontrollers are pre-programmed with the software. Kits also include PCB, AC adapter, and instructions on CD-ROM.

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PCBs can be bought separately.

Nixie Tube Clock Kit

October 2006

New & Improved Case!

Nixie tube clocks fuse the spirit, drama, and eerie beauty of cold war technology with modern inner works to create uncommon handcrafted timepieces.

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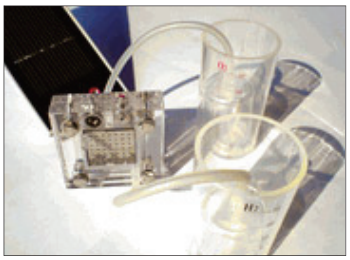
Kit includes article reprint, complete instructions, and parts list.

Solar Hydrogen Education Kit



The Solar Hydrogen Education Kit includes a solar cell, a PEM reversible fuel cell, oxygen and hydrogen gas containers, and more! The set only needs pure water to create hydrogen and produce electricity. Perfect for science labs, classroom use, or demonstration purposes.

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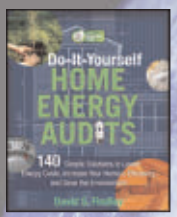

This new TAB Green Guru Guide offers complete details on assessing home energy efficiency, and offers 101 energy- and money-saving solutions. The author describes simple, no- and low-cost measures to identify problems and dramatically increase livability, efficiency, and expendable income each and every year. Information on energy grants, rebates, and tax credits is included.
$19.95

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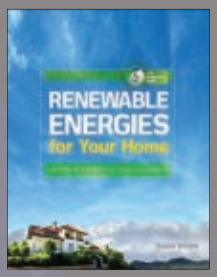
Renewable Energies for Your Home
by Russel Gehrke

Simple and Inexpensive Renewable Energy Solutions for Your Home.



It's not always easy being green, and sometimes it costs more than you'd expect to get an eco-friendly home improvement project up and running. *Renewable Energies for Your Home* gives you sustainable home energy solutions that won't drain your wallet or the power grid. Filled with step-by-step instructions and helpful photos and illustrations. **$24.95**

"Double Wide" Sun Tracker Kit

The Double Wide Sun Tracker is one of the great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 4 and 5, he teaches you how to get the most out of your PVs within the full day of sunlight. For kit details, please visit our webstore.

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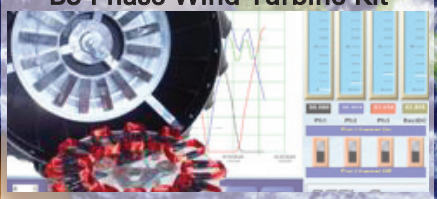
B3-Phase Wind Turbine Kit



The Whirlybird 3-Phase Wind Turbine Kit is one of the great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 6 and 7, he teaches you how to produce the most electricity utilizing the wind.
For kit details, please visit our webstore.

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WindPitch Kit

The WindPitch Wind Turbine Kit is a miniature real-working wind turbine and is one of the great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 8 and 9, he teaches you how to produce the most power by evaluating the pitch (setting angle) of the profiled blades. For kit details, please visit our webstore.

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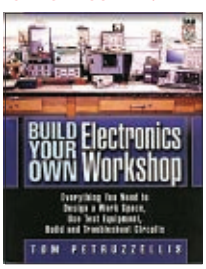
SPECIAL OFFER

Build Your Own Electronics Workshop
by Thomas Petruzzellis

YOUR DREAM ELECTRONICS LAB!



This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components, to putting the shop into action — building, testing, and troubleshooting systems. The best part is, this book will save you money.
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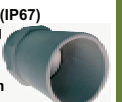

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continued from page 27

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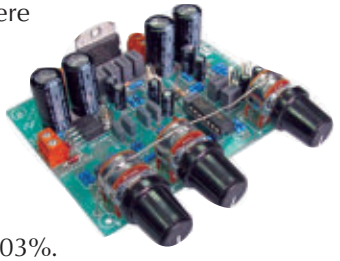

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>>> QUESTIONS

Measuring Frequency

I'm looking for a simple solution that measures the frequency of a pulse (.5 Vss). It does not need to measure higher than 1 kHz. Is there anything out there off-the-shelf or a kit; a small board with an LCD display?

#7101 **Rolf Breuer**
Cupertino, CA

Temp Controlled Fan

I need a circuit that can be used to control a 12V fan in a truck and tune to the needed temp. I would like to be able to use a standard automotive temp probe into the cooling system. I would like to do this with a display if possible but it is not necessary. I will actually be building three and tuning each a little higher to turn on the cooling fans.

#7102 **Dan**
Scranton, PA

Servo Motors

I am building a kinetic sculpture. I have a 5' wide plywood disk that weighs 50 pounds. I need to be able to spin the disk anywhere from between 60 to 500 RPM. Once the disk reaches a given RPM, I need the disk to maintain it precisely. Using just a normal AC motor doesn't work because the RPM seems to be constantly fluctuating. I am told that I need a .25 HP servo motor to achieve this. Any other ideas?

#7103 **Leif**
Los Angeles, CA

PWM Signal Generator For Camshaft-Pump Control

I am looking to do some development work of an injection pump in conjunction with a camshaft signal. I am looking to drive a coil with a resistance of 1.6 ohms (at 20 C), and an inductance at 1 kHz of 1.72 mH. The signal needs to be a (frequency 4 kHz) PWM peak and hold type with two parts: a V_boost and a V_hold (or V_batt). V_boost needs to be adjustable between 30 and 70V, and the current adjustable from 4 to 12A; V_hold should be adjustable between 6 and 18V. A zener diode should be used to drain the current from the coil when the driver is deactivated; V_zener should be 28V. The signal out sequence will be based on feedback from a once-per-rev Hall-Effect sensor; conversion to TTL would be fine.

The camshaft may have 2, 3, or 4 lobes, and therefore needs 2, 3, or 4 PWM peak and hold outputs per rev; evenly spaced. The maximum speed of the cam is 8,000 RPM. The signal start (or delay) must be adjustable from 0 to 360 degrees. The spacing of the signals must be 180 degrees for a 2 lobe cam, 120 degrees for a 3 lobe, and 90 degrees for a 4 lobe. I have the new 16-bit microcontroller demo, but I am new to it and so ICs may be better, based on my experience level.

#7104 **Matt McKean**
Detroit, MI

Sensor Matrix To Detect Objects

1. I'm looking for a low cost ($1 - $2) optical sensor solution to detect the presence of an object in a bin. The size of a bin varies between 5 cm to 15 cm. Sensor and LED light source would therefore need to be that far apart.

2. Bins are grouped in a matrix of 8 by 20, and their status needs to be collected periodically. What kind of a circuit would be the easiest way to collect the status of all bins?

#7105 **Rafael Skodlar**
Milpitas, CA

>>> ANSWERS

[#2107 - February 2010]

Battery Substitution

I have a Victoreen 592b Geiger type device. It requires nine batteries; six of them are the 22.5V photo style battery, the other three are unknown. There is no part number or voltage listed, but the location for them makes them as 1-1/8" diameter and a little over 1/2" high.

Can anyone help with the information so I can use my old friend?

#1 The battery (as you describe it) sounds like a Mallory RM-3R, 1.3V mercury cell; no longer made, as far as I know.

You should be able to substitute a 1.5V regular battery. The RM-3R had as much amp-hours as a D cell.

Do NOT substitute a 3V lithium battery as it will probably blow the tube filaments — yes, from the sound of the model number it was probably a vacuum tube design from the '50s.

Al. de la Lastra
via email

#2 I'm using a 78 year old brain to try to remember small details from over 30 years ago.

Thinking about it further, I think the mercury cell was 1.35 volts instead of 2.0 volts. I first started repairing those counters back in 1962 and at that time, Victoreen used brute battery force for power supplies. The 22.5 volt batteries produced the GM tube voltage and the mercury cells provided the circuit power. Victoreen used the mercury cells, in part, for the stable voltage characteristic over the life of the cell (from new to

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discharged.) A Google search for "mercury cell" gives battery specs and suggestions for replacement power supplies, as well as historical reasons mercury cells are no longer available.

Howard Darington
Salinas, CA

#3 In brief: The device uses three 1.3 volt and six 22.5 volt batteries. **www.orau.org/ptp/collection/surveymeters/Victoreen592B.htm**.

Max
Italy

[#2108 - February 2010] Vehicle Speed Threshold Trigger

To assist with parking, I'm installing front and side view cameras on my truck. The vehicle is already equipped with a rear view camera and I have a video switcher to select the desired view. As viewing video while driving may be dangerous, I want to disable the camera outputs at, say, 5 MPH.

I'd like to use a PIC to monitor vehicle speed and output a signal when the speed threshold is met. The truck's PCM currently provides a 5V square wave pulse signal which appears to be close to the actual vehicle speed (MPH), e.g., 12 Hz = 10 MPH.

While a PIC would certainly do the trick, you could also do the same thing with a retrigerrable monostable oscillator and a latch. Use one edge of the square wave from the PCM to (re)trigger the monostable; use the other edge to latch the output of the monostable. Arrange the hold time of the mono such that:

1 - When the PCM is slow enough, the mono times out before the latch is triggered.

2 - When it's too fast, the mono has not timed out.

There you go — use that latch output to enable the video.

Rusty Carruth
Tempe, AZ

[#3101 - March 2010] LCD TV Displays

I have a Casio portable color LCD TV (handheld) that has been made obsolete by the new digital signals.

I would like to use the display in an upcoming project.

I need information on driving color displays with a microprocessor.

#1 The Parallax Propeller can be used for as little as $8 to $10. It's surprisingly easy to program even though it has eight "cogs," each potentially capable of outputting its own analog TV video or VGA. The programming tool is free to use and may include a lot of sample code. Parallax provides generous support for doing projects with this chip, including video drivers.

The typical quality of its TV output is comparable to video game arcade or console machines made in the 1980s. (Its VGA output is limited by internal memory but can resemble PC video in various ways and by clever use of the memory.) It does need a COM port to program it. Although there are various ways of using USB to program it — which may cost more than the chip — it may also be a one-time cost.

Various board options are available for evaluating the chip and learning it quickly:

Hydra Propeller Game Console Kit: $199 (for serious interest in using Propellers; quickest learning).

Demo Board: Less than $100 (most popular configuration, but Hydra includes many accessories).

USB Proto Board: $39 (can be built up to and beyond demo board or custom configuration).

Total Do-It-Yourself: USB Propeller (programming) Plug: $29; Propeller Chip: $8; EEPROM Memory to store a program for booting: $2.

Other options include clever uses of a familiar and sufficiently fast microcontroller to generate video (which will require most of its clock cycles, assembly language, and detailed knowledge of the analog video waveform), or a serial module such as BOB3 which works with many different microcontrollers to display limited text and graphics using analog video.

William Como
Bethpage, NY

#2 Prof. Bruce Land designed an Atmel AVR generator capable of driving the video input of a TV. This may be a good match for what you want to do. This project is described in the Atmel Applications Journal, *Reference 1*. **Figure 1** shows one AVR pin outputting video summed with sync from another pin. The resulting composite video drives the TV video input. An 8 MHz crystal, Vcc, ground, and decoupling capacitors for the AVR are not shown. The reference lists a link to the code for this project. If you can program (burn) the code into the Mega163, the project can be duplicated.

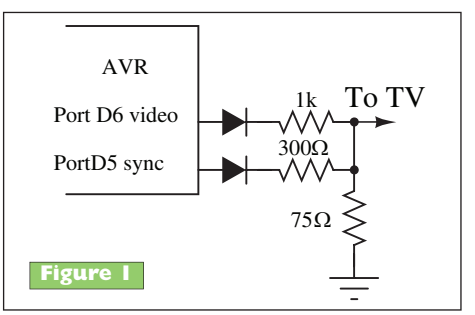

Figure 1

Reference:

1. Bruce Land, *Video Generator with an AVR Mega163*, at **www.atmel.com/dyn/resources/prod_documents/mega163_3_04.pdf**.

Dennis Crunkilton
Abilene, TX

[#3105 - March 2010] Dimmers

What is the difference between an ordinary light dimmer and a ceiling fan speed controller? They look the same

except one is twice the price.

Your question can be answered in detail in this application note: **www.st.com/stonline/products/literature/an/3566.pdf**.

You can't just turn on the triac at a particular point in the waveform and let it turn off at zero current because the voltage and current are not in phase in an inductive load. You need to continually trigger the device and turn it off at zero voltage.

The triac also has to be overrated to handle the motor load. This might require higher voltage components and components that can handle a higher current and greater heatsink area (all which would increase cost). The designs shown in the application note do not show protective devices or snubbers (RC networks) that are required for the triacs.

Ron Dozier
Wilmington, DE

[#3104 - March 2010]
DC Electric Motor

How does one find the wattage of a 24 VDC motor that has no name plate? I need a speed control for my electric bike, but they all want to know the wattage of the motor.

#1 The answer is long and complicated, but in short, the wattage of any DC motor is based on the maximum operating temperature it can endure and it varies with RPM. In your application though, we can use another clue to help us: the wire size on the motor. It is probably 14 or 16 ga so you're looking at 12-15 amps. Assume the worst and go with a 400W controller for reliability; half a horsepower on a bike should be enough!

Dan Danknick
Santa Ana, CA

#2 Watts = Volts multiplies by Amps. See this website: **www.electoolbox.com/Formulas/Useful/formulas.htm.** So to get the watts, you need to know the amps the running motor is using. To do that, you need to put a meter that can read the current of the circuit "within" the circuit so that it is a part of the circuit and can read the current flow. See this webpage for an example: **www.electronics-radio.com/articles/test-methods/meters/how-to-measure-current.php**.

Wesley Miller
Dillsburg, PA

Comments

There was an answer published in the March edition of *Nuts & Volts* to the question:

I would like to know what kind of programming is used in a car ECU. Is it C, C++, Visual Basic or something else?

Although I don't work with spark ignited ECUs, the diesel variety are developed in a similar manner and the question I think being asked is what is the coding language?

The steps in development and then production run something like this:

The development of control is done in simulation often using Mathworks Simulink — a graphical language looking something like LabView.

The result is converted from Simulink diagrams into either processor specific objects or C source.

Assuming C source, the code is combined with extensive libraries of supporting code in a development environment such as Rational Rose or Beacon, etc.

The result of the compilation is both an executable object and test vectors required for extensive and intensive testing.

The testing is performed on testbed ECUs and development prototyping tools such as those by D-Space. The testing continues on prototype engines in engine test cells and test vehicles in all types of conditions.

The development process is so costly and time-consuming that many derivative ECU feature configurations use the same code base. This is possible because the design is centered around algorithms that are configured by variables that can be set separately from building new code. Just like the formula y = a*x+b produces different values for Y, depending on the values for a and b.

Tools for making these changes in variables are often built on the ASAP standards from Europe. The tools are called calibration tools (not like calibrating a sensor but rather changing how the software works by changing variables).

So the coding is done in diagrams in Simulink, coded in C, compiled to binary, and loaded into a Flash memory with variables modified by ASAP tools to work in a particular vehicle with a particular engine and customer options.

The question may be from the idea that maybe the ECU can be hacked. Very unlikely as there are thousands of settable parameters and a lot of precise interactions between them. Some people try to manipulate the ECU by changing the sensor values wired to the ECU but often the software can detect these attempts and make the result worse, not better.

Don Baker

Automotive control systems are one type of embedded system which means that there is no keyboard for input or display for output. An ECU listens to various sensors like O_2 in exhaust, engine RPM, throttle position, engine temperature, etc., and controls things like fuel injection timing and amount, spark timing, radiator fan speed, etc. As for the language that is used to program these units, most (if not all) manufacturers adhere to the MISRA guidelines for using the C language in critical systems. Visual languages are great for writing applications on your desktop computer but are ill suited for the demands of an industrial control system. You can learn more about MISRA C via this link: **www.misra-c2.com**.

Dan Danknick

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Cunard Associates 28
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Futurlec 37
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Saelig Company, Inc. 19
V-Module 50

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Electronix Express 43
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Futurlec 37
Jameco 4
Linx Technologies 50
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V-Module 50

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ActiveWire, Inc. 28
Electronic Surplus 25

Microcontrollers / I/O Boards

Abacom Technologies 8
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Fun Gizmos 28
HobbyLab 28
I/O Bridge 19
microEngineering Labs 64
MikroElektronika 3
Mouser Electronics 9
Net Media 2
Parallax, Inc. .....Back Cover
Pololu Robotics & Electronics 56
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Technological Arts 28
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ExpressPCB 32
General Circuits / PCB Cart 56
PCB Pool 63
Trace Systems, Inc. 65

EDUCATION

BaneBots 33
Command Productions 27
I/O Bridge 19
LearnOnLine, Inc. 65
NKC Electronics 28
Technological Arts 28

EMBEDDED TOOLS

Mouser Electronics 9
NetBurner 7

ENCLOSURES

Integrated Ideas & Tech. 18

ETHERNET

Custom Computer Services 63

KITS & PLANS

Cana Kit Corp. 55
Custom Computer Services 63
DesignNotes.com, Inc. 28
Jaycar Electronics 51
NetBurner 7
NKC Electronics 28
QKITS 28
Ramsey Electronics, Inc. 20-21
Solarbotics/HVW 65

MISC./SURPLUS

All Electronics Corp. 57
Electronic Surplus 25

MOTORS

BaneBots 33
Electronic Surplus 25
Jameco 4

PROGRAMMERS

Futurlec 37
microEngineering Labs 64
MikroElektronika 3

PROTOTYPING

PrintAProto 28

RF TRANSMITTERS/ RECEIVERS

Abacom Technologies 8
Linx Technologies 50

ROBOTICS

BaneBots 33
Fun Gizmos 28
HobbyLab 28
Jameco 4
Lemos International Co., Inc. 13
Lynxmotion, Inc. 71
Net Media 2
Pololu Robotics & Electronics 56
Robot Power 28
Solarbotics/HVW 65
Zagros Robotics 28

SATELLITE

Lemos International Co., Inc. 13

SECURITY

PolarisUSA Video, Inc. 13
Technological Arts 28

SOLAR ENERGY

LearnOnLine, Inc. 65

TEST EQUIPMENT

Circuit Specialists, Inc. 82-83
DesignNotes.com, Inc. 28
Dimension Engineering 33
HobbyLab 28
Jaycar Electronics 51
LeCroy 5
NKC Electronics 28
Pioneer Hill Software 56
Saelig Company, Inc. 19
Trace Systems, Inc. 65

TOOLS

MikroElektronika 3
NetBurner 7

WEB SERVICES

I/O Bridge 19

WIRE, CABLE AND CONNECTORS

DesignNotes.com, Inc. 28
Jameco 4

Abacom Technologies 8
ActiveWire, Inc. 28
All Electronics Corp. 57
AP Circuits 13
BaneBots 33
Cana Kit Corp. 55
Circuit Specialists, Inc. 82-83
Command Productions 27
Cunard Associates 28
Custom Computer Services 63
DesignNotes.com, Inc. 28
Dimension Engineering 33
Electronic Surplus 25
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ExpressPCB 32
Fun Gizmos 28
Futurlec 37
General Circuits / PCB Cart 56
HobbyLab 28
I/O Bridge 19
Integrated Ideas & Tech. 18
Jameco 4
Jaycar Electronics 51
LearnOnLine, Inc. 65
LeCroy 5
Lemos International Co., Inc. 13
Linx Technologies 50
Lynxmotion, Inc. 71
microEngineering Labs 64
MikroElektronika 3
Mouser Electronics 9
NetBurner 7
Net Media 2
NKC Electronics 28
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PCB Pool 63
Pioneer Hill Software 56
PolarisUSA Video, Inc. 13
Pololu Robotics & Electronics 56
PrintAProto 28
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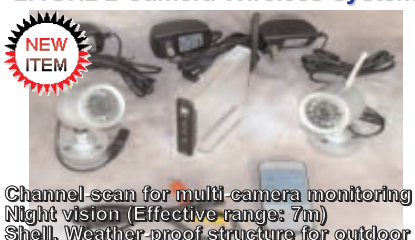

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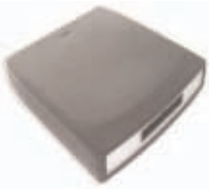
www.circuitspecialists.com/DSO-2150

100HMz DSO-2250 $249.00
www.circuitspecialists.com/DSO-2250

200MHz DSO-5200 $289.00
www.circuitspecialists.com/DSO-5200

Specifications	DSO-2090	DSO-2150	DSO-2250	DSO-5200
Channels	2 Channels			
Impedence	1M 25pF			
Coupling	AC/DC/GND			
Vertical resolution	8 Bit			9 Bit
Gain Range	10mV-5V, 9 Steps			10mV-10V, 10Steps
DC Accuracy	+/- 3%			
Timebase Range	4ns - 1h 38 Steps			2ns-1h, 39 Steps
Vertical adjustable	Yes			
Input protection	Diode clamping			
X-Y	Yes			
Autoset	30Hz~40MHz	30Hz~60MHz	30Hz~100MHz	30Hz~200MHz
EXT. input	Yes			
Trigger Mode	Auto / Normal / Single			
Trigger Slope	+/-			
Trigger Level Adj.	Yes			
Trigger Type	Rising edge / Falling Edge			
Trigger Source	Ch1 / Ch2 / EXT			
Pre/Post trigger	0-100%			
Buffer size	10K-32K per ch			10K-512KB per ch
Shot Bandwidth	DC to 40MHz	DC to 60MHz	DC to 100MHz	100MHz
Max Sanple Rate	100MS/s	150MS/s	250MS/s	250MS/s
Sampling Selection	Yes			
Waveform Display	port/line, waveform average, persistence, intensity			
Network	open / close			
Vertical Mode	Ch1, Ch2, Dual, Add			
CursorMeasurement	Yes			
Spectrum Analyzer				
Channels	2 Channels			
Math	FFT, addition, subtraction, multiplication, division.			
Bandwidth	40 MHz	60 MHz	100MHz	200 MHz
Cursor	Frequency, Voltage			
Data Samples	10K-32K/Ch			10K-1M/Ch

34 Channel USB Logic Analyzer



The CSI5034 is a sophisticated, portable, and easy-to-use 500MHz, 34-channel logic analyzer equipped with features found only in more expensive bench type instruments.

Using advanced large-scale integrated circuits, integrated USB 2.0, CPLD, FPGA, high-frequency digital circuitry, embedded systems, and other advanced technology, make the CSI5034 your best choice in pc-based logic analyzers The CSI5034 is suitable for electronic measurement engineers, college students in scientific research and development and teaching assistants.

- 34 input channels capable of simultaneously monitoring data and control information, and is capable of capturing narrow pulses and glitches that may be missed by other test equipment.
- Delay feature provides the ability to capture data around the waveform, both before and after the desired trigger signal. This allows the operator to view the data at multiple points in the data stream
- Memory feature stores multiple data points for error analysis of the unit under test and to aid in locating defective components.
- Intuitive and flexible viewing screens to facilitate analysis of the system under test. Data can de displayed as binary, decimal, or hexadecimal values.
- Can be triggered in a variety of ways (rising edge, falling, edge or both) , and also has an advanced trigger function that allows logic operations to be performed on the data before a trigger is generated. This provides the ability to trigger on a specific data byte or word from any of the monitored channels.

NEW ITEM

Item # CSI5034 $329.00

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Adjustable DC Power Supplies with Adjustable Current Limiting

NEW ITEM

Regulated linear power supplies with adjustable current limiting. The LED display shows both Volts & Amps. The current output can be preset by the user via a front panel screwdriver adjustment screw while the voltage is adjustable by a front panel multi-turn knob for precise voltage settings. Output is by front panel bananna jacks and there is also a covered terminal strip for remote voltmeter sensing at the load.

* Utilizes SMD technology
* Pre-Settable Voltage & Current levels
* Front Panel On/Off Switch
* Large LED readout for Voltage & Current
* S+ & S- Sampling terminals

0-30 Volt / 0-10 Amp Adj.	(CSI3010X)	$198.00
0-30 Volt / 0-20 Amp Adj.	(CSI3020X)	$299.00
0-40 Volt / 0-10 Amp Adj.	(CSI4010X)	$269.00
0-60 Volt / 0-10 Amp Adj.	(CSI6010X)	$319.00
0-120 Volt / 0-3 Amp Adj.	(CSI12003X)	$265.95

www.circuitspecialists.com/dcpower

Programmable DC Electronic Loads

These devices can be used with supplies up to 360VDC and 30A. It features a rotary selection switch and a numeric keypad used to input the maximum voltage, current and power settings. These electronic DC loads are perfect for use in laboratory environments and schools, or for testing DC power supplies or high-capacity batteries. It also features memory, and can also be connected to a PC, to implement remote control and supervision.

360V/150W (CSI3710A) $349.00

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360V/300W (CSI3711A) $499.00

www.circuitspecialists.com/csi3711a

60MHz Hand Held Scopemeter with Oscilloscope & DMM Functions

Who Says you can't take it with you?

With the DSO1060 YOU CAN!

You get both a 60 MHz Oscilloscope and a multi function digital multimeter, all in one convenient lightweight rechargeable battery powered package. This power packed package comes complete with scopemeter, test leeds, two scope probes, charger, PC software, USB cable and a convenient nylon carrying case.

- 60MHz Handheld Digital Scopemeter with integrated Digital Multimeter Support
- 60MHz Bandwidth with 2 Channels
- 150MSa/s Real-Time Sampling Rate
- 50Gsa/s Equivalent-Time Sampling Rate
- 6,000-Count DMM resolution with AC/DC at 600V/800V, 10A
- Large 5.7 inch TFT Color LCD Display
- USB Host/Device 2.0 full-speed interface connectivity
- Multi Language Support
- Battery Power Operation (Installed)

Item # DSO1060 **$569.00**

www.circuitspecialists.com/DSO1060

60MHz Hand Held Scopemeter w/Oscilloscope, DMM Functions & 25 MHz Arbitrary Waveform Generator

- All the features of the DSO1060 plus a 25 MHz Arbitrary Waveform Generator.
- Waveforms can be saved in the following formats: jpg/bmp graphic file, MS excel/word file
- Can record and save 1000 waveforms
- DC to 25 MHz Arbitrary Waveform Generator

Item # DSO-8060 **$659.00**

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POTRANS [Special Purchase]

150Watt 24V/6.5A Switchable Power Supply

* High efficiency
* High reliability
* Protection: Over-voltage/Over-current/Over-power/Short-circuit
* Output reverse protection
* VAC input range selected by switch
* 100% full load burn-in test
* EMI/RFI: FCC Part 15J, Class A & CISPR 22 Class A

Item # CSI-15024-1M

1+$19.00 10+$14.95 100+12.95

UL, cUL, CCC, CE & TUV approved

Programmable DC Power Supplies

- Up to 10 settings stored in memory
- Optional RS-232, USB, RS-485 adapters
- May be used in series or parallel modes with additional supplies.
- Low output ripple & noise
- LCD display with backlight
- High resolution at 1mV

Model	CSI3644A	CSI3645A	CSI3646A
DC Voltage	0-18V	0-36V	0-72V
DC Current	5A	3A	1.5A
Power (max)	90W	108W	108W
Price	**$199.00**	**$199.00**	**$199.00**

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BK3000LF Compact Lead Free Soldering Station **$59.00**

BK4000 Thermostatically controlled desoldering station **$99.00**

BK4050 HotAir System w/Vacuum IC handler & Mechanical Arm **$99.00**

BK5000 Hot Air System w Soldering Iron & Mechanical Arm **$99.00**

BK6000 Premium All-In-One Repairing Solder System **$199.00**

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0-30V / 0-5A . DC Power Supply

NEW ITEM

The CSI530S is a regulated DC power supply which you can adjust the current and the voltage continuously. An LED display is used to show the current and voltage values. The output terminals are safe 4mm banana jacks. This power supply can be used in electronic circuits such as operational amplifiers, digital logic circuits and so on. Users include researchers, technicians, teachers and electronics enthusiasts. A 3 ½ digit LED is used to display the voltage and current values.

ww.circuitspecialists.com/csi530s

Item # CSI530S **$79.00**

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Breadboard-Friendly!

Human Interface Devices

Breadboard-friendly products pictured clockwise from upper left:

NES Gamepad Controller Adapter (#32368; $9.99) - Easily connect two NES-style gamepad controllers (#32365; $4.99 each) to a breadboard. Gamepad sockets are routed to a dual row of pins for stability, with data connection indicator LEDs and series resistors for I/O pin protection.

Absolute Rotary Encoder (#27804; $9.99) - A mechanical encoder capable of rotating a full 360° in both the clockwise and counterclockwise directions without limits. This device can also relate its current position relative to one of sixteen points on the encoder.

Trackball Module (#27908; $14.99) - Similar to the trackball found on many smart phones, this sensor is portable and can replace a mouse in many applications. Comes with a built in center select switch and a programmable red LED.

4x4 Matrix Keypad (#27944; $19.00) - This keypad has conductive rubber contacts with an operational life of 3 million cycles, and a good tactile feel for positive feedback. Keypad Cable (#27943; $7.99) is recommended and sold separately.

2-Axis Joystick (#27800; $4.99) - Joystick has two independent potentiometers (one per axis) for reporting the joystick's position with wiring options for voltage or resistance outputs, spring auto-return to center and comfortable cup-type knob.

5-Position Switch (#27801; $4.99) - It's a normally open contact switch that provides directional output to your project. This switch has a nice snappy feel, and returns to the center/un-pressed position immediately when it is released.

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